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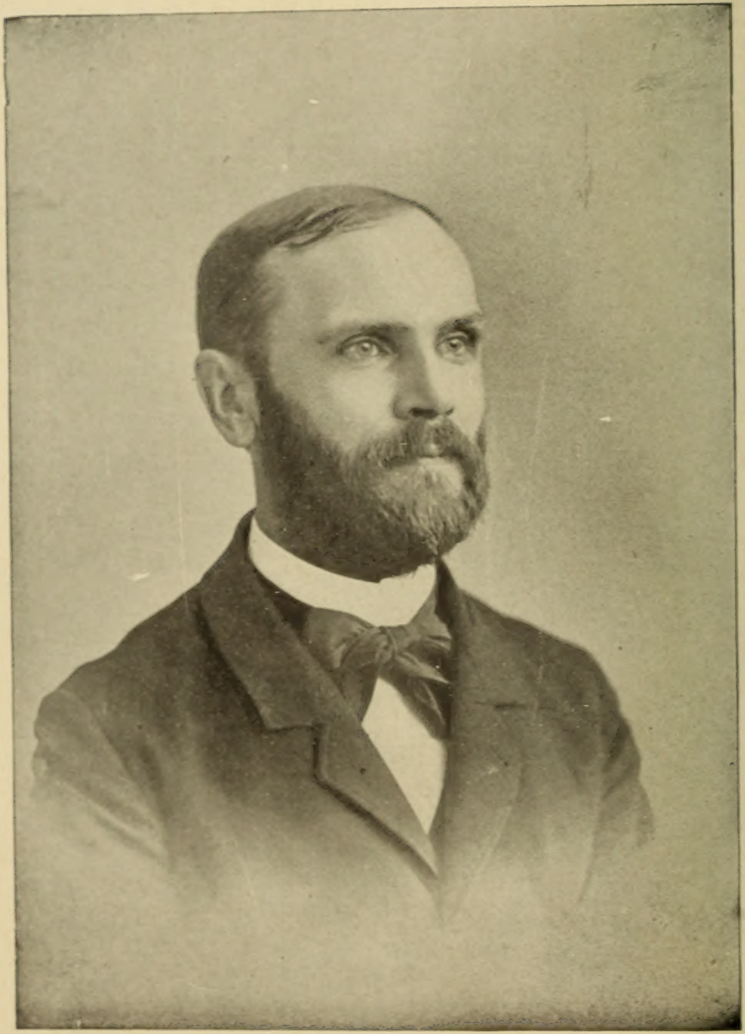

JOHN McGOVERN.

The New Fireside University

for Home Circle Study or Familiar Talks

ABOUT COMMON THINGS

WITH COMPLETE INDEX

ILLUSTRATED

BY

JOHN McGOVERN

AUTHOR OF

"HISTORY OF MONEY, BANKING, STOCKS AND BONDS,"
"HISTORY OF GRAIN AND THE GRAIN TRADE,"
"THE EMPIRE OF INFORMATION,"
"THE TOILER'S DIADEM,"
"THE GOLDEN CENSER," ETC.

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PUBLISHERS' PREFACE.

THE author of THE FIRESIDE UNIVERSITY was requested to entirely avoid, if possible, a technical description of the arts, sciences and manufactures, and to write a book for the masses of the people. It is hoped that every person who can read and write may read this book with interest, and derive benefit from it.

The advancement of science and invention has been so rapid, and the organization of labor has become so complex, that within a few decades the masses have been entirely shut away from a knowledge of the means by which their existence is made pleasant, comfortable, and even luxurious. It is the object of this book to supply some of this knowledge.

The spirit of this book, and the need for it, are illustrated in the following fact: Covering one, two, three, four, five city blocks, there arises the enormous Glucose Factory, grinding one hundred thousand bushels of corn daily. The people look with wonder upon this rising and increasing pile of buildings (whose inmates seem to be forever at toil), with no thought that at the beginning there was only a chemist at work in his little laboratory, developing certain ideas. Between his ideas, his hopes, his glass tubes and his multitudinous apparatuses, and this monstrous concrete thing called the Glucose Factory, there is an astonishing gap in the people's knowledge. How did it come to develop so completely, before they had grasped even the idea of the chemist and the inventor

The Glucose Factory gives us but a single illustration of what has happened on every side of us. The nickel-plated ornaments, the finely spun fabrics, the beautifully colored prints, the swiftly flying street car, the glowing splendor of the modern night lit with thousands of incandescent lamps, the astonishing cheapening of all articles that once were so costly that only a king could buy them—all these make chapters of marvelous charm, more certain of any reader's attention than the most fascinating novel ever written. Every page is full of curious and wonderful things.

On the other hand such a book necessarily touches all the practical phases of our latest civilization. Incidentally the physical needs of the human race are classified thus ;

1st. Foods and food supplies of the world.

2d. The clothing and sheltering of the human race.

3d. Heating and lighting of the world.

4th. The power supply of the world.

5th. The modes and means of travel, traffic and the exchange of thought.

To each of these the highest inventive genius and most skilled labor have lent their energies, and in each of these great needs every thinking human being is deeply interested.

We believe no other such book exists, and we present this work for the inspection of the people, sincerely hoping that it may interest them, as being strictly in accord with the trend of modern general intellectual progress.

THE PUBLISHERS.

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What is the Latest Scientific View?

As early as the summer of 1907 Sir William Ramsay publicly asserted and demonstrated his theory of the Degradation of the Elements, and it became practically the view of the British Association for the Advancement of Science.

Why not call it Transmutation of the Elements?

You may. But the Transmutation now discovered is downward—that is, Elements become lighter (have less gravity) as they change into other Elements, whereas the alchemists of other days hoped to transmute baser Elements into nobler ones —Copper into Silver or Gold.

Sum up the Recent Stages in this Theory.

The base of the discoveries lay in Electrolysis—what we generally call electro-plating. The then peculiar action of Electricity in liquids set men to confine gases in tubes where still more puzzling effects followed. Then, after the Geissler, Lénard, Crookes tubes, came Dr. Roentgen's X-ray; then J. J. Thomson's discovery that the particles flying from the negative pole, through the compressed gases, must be lighter than the atom of Hydrogen; then Madame Curie's discovery of Radium, which has proved to be the modern philosopher's stone, for, by the study of its Emanations (p. 553), the break-down of Elements has been perceived. Meanwhile, you are to consider Mendeléeff of Russia as the Darwin of Chemistry He collated men's chemical discoveries, described Elements in advance of

their discovery (or "isolation"), and died in a glory that cannot fail to increase with time. As soon as Mendeléeff had told men the relations of their discoveries, investigators made a progress marvelously more rapid.

What is an Electrolyte?

An Electrolyte (Electrolysis, pp. 88, 282,) is an aqueous solution of acids, bases and mineral salts, or these latter bodies in a fused condition. Ionization takes place.

What is that?

It is believed that the molecule of a dissolved substance forms two ions—one of Hydrogen or metal, positive; the other an acid radicle (p. 238), negative. A current sets up, and each ion carries its load to the opposite pole. Hence an-ion and cat-ion, like anode and cathode. Madame Curie and her husband, noting that there was always a transportation of matter in Electrolysis, adopted the theory of the atomic character of Electricity, and they declared that this theory led them on to the discovery of Radium and the astonishing development of our knowledge of radio-activity in matter. Madame Curie, like J. J. Thomson, found that positive electricity revealed itself in very considerable atoms, while negative electricity moved in particles so small that they seemed to be super or intra material—like the Ether. She called the negative particles electrons. And here is a thing you will do well to place among fundamental thoughts—namely: Where these electrons move, their mass increases with their velocity toward an infinite speed limited by the speed of light. That is, electricity is forever approximating the speed of 186,000 miles a second, but mathematically will never reach it.

What else did Madame Curie do?

She found that Actinium, as well as Radium, would break down into Helium. She placed Polonium, an Element which she had discovered, as probably the last of the radio-active series. To the end, she and other investigators found that all Transmutations were carried on by Nature entirely independent of the operator. She has encouraged the labors of Rutherford,

Ramsay and Soddy. She believes that a study of the proportion of Elements in the rocks and their relative radio-activity will reveal our best knowledge of their age. She feels that the mysteries of the Sun's phenomena, as frankly acknowledged by masters like C. A. Young and Langley, will now be approached through the knowledge we are attaining of radio-activity.

Have all the Ponderable Elements been Solidified?

All save Hydrogen, the instrument of operation. On March 21, 1908, Professor Ohnes, of Leyden University, telegraphed to Professor Dewar, of the Royal Institute at London: "Converted Helium into a solid. Last evaporating parts show considerable vapor-pressure, as if liquid state is jumped over." At the low temperature required for the solidification of Helium, all the rest of the world, excepting Hydrogen (then a liquid) is a solid —that is excepting the celestial Elements, the ones discovered by the spectroscope far from the Earth, or its surface.

What are those "Celestial Elements"?

Coronium, Nebulum, Aurorium, Asterium. But all of these (and others) are doubtless present on or about the Earth. Coronium has been recognized at Mount Vesuvius (p. 222). Asterium (p. 558) is the *ne plus ultra* of the new sub-atom theory.

How am I to grasp this Theory of Degradation?

First, take Mendeléeff's Table, at p. 547, and retabulate it, so that the Elements of a Group will decrease in weight rather than increase—that is, put Hydrogen at the bottom of Group I, and Gold at the top; Helium at the bottom of the Zero Group, and Xenon at the top, etc. Now when a radio-active Element, in one of these columns, "emanates", that emanation may produce another Element, but that Element will be further down the column of your retabulation than the parent radio-active Element was—although there may be a migration into some adjacent or nearby column. Thus, the first discovery was that Radium, in Group II, at 225 Hydrogen-weights, produced Helium in the Zero Group at 4.

What next?

Sir William Ramsay announced to the Association that Radium-Emanation also produced Argon at 38, and Neon at 19.9, of the Zero Group.

And what more?

He announced that Copper, of Group I, at 63.6, acting under the influence of Radium Emanation, produces Lithium, further down, at 7.03 in your retabulation (or further up the column in Mendeléeff's Table). To change Copper into Lithium is a truly astonishing thing, for in appearance they look not alike at all. Lithium is a white metal, that makes the beautiful red of fireworks, and the gleaming red lines in the spectroscope. But for the necessity of operating in vessels of glass, Professor Ramsay would have announced also that he had beheld the similar creation of Sodium and Potassium.

What did he think Radium Emanation was?

He thought the emanation with which he operated (see various Radium Emanations, p. 553) belonged to the Helium Series of Elements—(that is, cross-wise of your Table at Helium). He said, and we should read it with great care: "From its inactivity, it is probable that Radium Emanation belongs to the Helium Series of Elements. During its spontaneous change it parts with a relatively enormous amount of energy. . . . If the Emanation is alone, or in contact with Hydrogen or Oxygen gases, a portion is decomposed, or disintegrated, by the energy given off by the rest. The gaseous substance produced is, in this case, Helium. If, however, the distribution of the energy is modified by the presence of water, that portion of the Emanation which is decomposed yields Neon; if in the presence of Copper Sulphate, Argon. Similarly, the Copper acted upon by the Emanation is degraded to the first member of its Group, namely, Lithium [the Professor does not reckon Hydrogen]. It is impossible to prove that Sodium and Potassium are formed, seeing that they are constituents of the glass vessel in which the solution is contained, but from analogy with the decomposition-products of the

Emanation, they may also be products of the degradation of Copper."

What was the Philosopher's Stone?

The alchemists believed that an alloy was a diseased metal or Element. It would naturally often present itself to them as an ore, or "stone". If they could find a certain ore, and "cure" it, they would have Gold—there were three Golds. If they could get the third Gold and liquify it, they would have the Elixir of Life, by which to live indefinitely. They believed—as scientists are now forced to theorize—that Nature was composed of one Element. In fact, it would seem to be a law of human reasoning that we adjust our primitive beliefs instead of abolishing them. The alchemists noted the peculiarities of many Elements, and wrought with those which to-day are found to be of radioactive character. Our philosopher's stones of to-day are Radium, Thorium, Actinium, Uranium, Polonium, etc., but they work the wrong way to suit the theory of the alchemists. Yet the astonishing thing of these twentieth century observations is that the essence of a theory that was laughed at for two centuries or more—in fact, Dante's poem was an attack on the theory—proves to have been correct as measured by the electric tube, the electroscope, and the bolometer. The alchemists were especially ridiculed for founding most of their hopes on so base a metal as Lead, yet Lead is in the Thorium and Cerium Group, and in the Gold Series, as your table will show you.

What has taken place in Astronomy?

Among other interesting things accomplished by astronomers, Prof. E. E. Barnard, discoverer of the fifth satellite of the planet Jupiter, has published observations of a sixth satellite of the giant planet. He has followed this with "Observations of Phœbe, the ninth satellite of Saturn." The seventh and eighth satellites of Jupiter have been discovered and photographed.

What is Vigneron's Description of the Magnetic Atom?

As soon as Science accepted the hypothesis of the Electron, or *electric* fragment of an atom, there was imposed the corollary

theory of a Magneton, or *magnetic* fragment of an atom. A magnet does not always have the same *moment* (tendency to produce motion), but varies in power with temperature, chemical composition, etc. But it is found that these different values have simple ratios one to another. "We can thus find among the atomic *moments* of a single metal an aliquot part. It will then be found that the aliquot parts of the different atoms are all the same; and to this common value the name of Magneton has been given." The demonstration was first made for the rare earths, and for Iron, Cobalt, Chromium, Manganese, Copper and Mercury. It is suggested that the theory of the Magneton may offer a key to the mystery that surrounds the "irregularity" of grouping of the lines of the spectra of the Elements. It is now scientifically conceivable that, when matter "transmutes," it may also vary in energy.

Is There a Caloric Atom, or Atom of Heat?

It may be that the disturbance of previous theories caused by Prof. Roentgen's X Ray will involve a return to the ancient Caloric theory. Prof. H. L. Callendar, of the British Association of Science, now holds that what we have called "heat" is only the *energy* of heat. Heat may be a substance, as water is; the water passes over a mill-wheel and turns it; a portion of the water's *energy* is now gone, but the water has not diminished proportionally. The lost *energy* has been called *entropy* by the engineers, and thereafter counted as an abstraction. But, as the electric fluid was once an abstraction, and is now computed as an electron, so entropy must now be accounted for in a material showing. Prof. Callendar thinks that when the positive charge of electricity shall be espied in something smaller than a Hydrogen atom, this as-yet-undiscovered heat-atom may be found to be a doublet of matter made neutral electrically by the union of a positive and a negative corpuscle of Electricity. These doublets, passing through any body, like a bar of Iron, might issue as heat and entropy, both instead of one having more than a merely mathematical existence.

Note—Our chapter on Chemistry, at p. 226, will prepare the reader for the notes at p. 222, etc., from which he may proceed to p. 535, and thence to "The Advance of Science" at p. 544. Thereafter, adding these Bulletins of Tentative Science, he may justly consider himself in philosophical harmony with the stars.

WIRELESS TELEGRAPHY. (Page 103).

OPERATOR SENDING THE EXACT TIME FROM A WIRELESS OBSERVATORY.

Electricity.

What is Electricity?

It is believed to be one of the many demonstrations of what may plainly be called physical force.

What are the other leading demonstrations of physical force?

They are called Motion, Heat, Light, Magnetism and Chemical Affinity.

Are there still other forms of force?

Yes. Gravitation, Inertia, Aggregation and Animal Life itself.

What is the doctrine of the conservation and correlation of forces?

It is a theory, promulgated as early as January, 1842, by William Robert Grove, and in 1843 advocated or demonstrated by Dr. J. P. Joule, both Englishmen, to the effect that light, heat, motion, electricity, etc., can be turned into one another without loss—in other words, that both motion and matter are indestructible.

When did this theory become common with all classes of the people?

As early as 1870.

Will you describe Electricity as Grove described it?

"Electricity is that affection of matter or mode of force which most distinctly and beautifully relates other modes of force, and

exhibits, to a great extent in a quantitative form, its own relation with them, and their reciprocal relations with it, and with each other."

To what form of force can you most readily liken it?

To the X ray. Electricity is invisible, formless, without taste or smell, and acts through bodies of matter.

Why is it, so far as the people are concerned, the most interesting form of force?

Because there is a likelihood that Electricity will furnish light, heat, transportation and traction power, news-transmission, and possibly medical aid to all the people.

Should such results be accomplished, what good would follow?

The hard labor of the world would be reduced almost to zero, and the mental progress of the people would be enhanced.

What cosmic theory seems to flourish most generally with the scientist?

The etheric theory, which supposes that all bodies of matter are comparatively loose aggregations of atoms (molecules), through which the ether moves as easily as water through gravel.

What follows?

It may be that each molecule revolves in its own orbit or vortex. Certain forces may make the atoms go round one way and other forces may reverse the motion.

What other action may take place?

Certain forces may decompose the molecules, causing them to unite differently.

When Electricity is used as this decomposing force, what is the act of decomposition called?

Electrolysis. Here is the theory of Grotthus: Two plates of opposing metals—say a sheet of zinc and a sheet of copper—are immersed in sour water after the manner of the Voltaic battery. One of the sheets of metal attracts the molecule of oxygen in the nearest molecule of water, and the oxygen separates from the hydrogen which is its companion. This

hydrogen, thus left alone, goes over and joins the next water molecule, which forces away some more hydrogen, to go to the next molecule, and so across to the other metal plate, the so-called current being nothing else than this molecular movement. This, you will notice, presupposes that water is a mass of hydrogen-oxygen molecules poised in the etheric fluid or medium.

What is Aggregation?

A term used in denoting the potential state of what we call a solid, a fluid, or a gas. An ideal body of gas, in the ether, is said to have reached an *adiabatic* state. Should it solidify suddenly it would demonstrate its maximum of force, or if the aggregation be already solid, the reverse might follow its expansion.

Where does the word Electricity originate?

In the Greek word *Electron*—that is, amber. Amber was one of the chief articles of commerce with the Phœnicians, before the days of the Greeks. The Phœnicians had a route across Europe from Lyons to the North Sea, where they gathered the gum. Thales, the Greek philosopher, 600 B. C., studied the attractive power of amber when rubbed.

Was amber the only body that could be rendered attractive by rubbing?

No, it was eventually found that if any two bodies were rubbed the one might attract and the other repel light substances, such as hairs and feathers. Thus, Electricity came to be called positive and negative, and in the books of to-day the Electricity set up in glass is called positive or *plus* and that set up in resins is called negative or *minus*. Two *plus* bodies repel each other. Two *minus* bodies repel each other. One *minus* body repels a non-electric body. All other combinations in which one *plus* body enters attract each other.

Is the electrical spark Electricity?

No. Grove early taught that there could be no emanation of the electric fluid, for, in his opinion, no fluid existed. Two electrodes, after contact and gradual separation, could in those days be widened (in a vacuum) as much as seven inches,

and the brilliant light would travel across in a steady stream. This light was discovered by Grove to be an emission of the matter itself from the point whence the fire issued, and a molecular action of the medium, (air, gas or ether) across which the light was transmitted. Thus the streak of lightning is red-hot air. The color of the Voltaic arc—(*Arc* here means the streak of fire, because in the days of Sir Humphrey Davy, when the metal electrodes or carbon candles were always held horizontally, the fire in crossing curved upward, an action due to atmosphere and earth magnetism)—this color varies with the metal used for the transmission of the Electricity. With zinc, the light is blue; with silver, green; with iron, red. A portion of the metal is also found to be transmitted with the discharge.

Is the arc light an ignition or a combustion?

Not strictly either. The matter which separates is more than heated, therefore it is not ignition. It is not combustion, for the arc will play in a vacuum, or without air, oxygen, or any of the bodies usually necessary when matter is chemically united with the attendant phenomena of light and heat. Again, in a vacuum, the electrodes deposit their particles on the inside of the receiver, and these particles are in an unaltered state.

What hypothesis would it be wise for the unscientific student or thinker to adopt concerning force?

It may be recommended, as the simplest plan, to regard the Sun as the original engine of force, and what we call Light as the means of transmission of the sun's force to the Earth. Then every demonstration of force that we see had its origin in the Sun, and was stored in the Earth before it was liberated, or unbalanced. Thus useful Electricity is always obtained at a great expenditure of other power, and only with attendant loss. When the amber was rubbed, the power used in rubbing it was conserved or stored in the amber, ready to be liberated into the body of matter that was in the best state of affinity.

When the amber was rubbed, would the amount of rubbing make any difference, and would a piece of amber give off more or less power?

Yes. It was early determined that the terms Resistance, Electro-motive Force, Capacity, Quantity, Work, Induction and Power might be distinctively applied to bodies that had been rubbed, or to bodies that were contributory or dependent on the rubbed bodies of matter. As electrical science developed, it became as necessary to measure by these terms as to measure wheat by the bushel or cloth by the yard.

What is the system of electrical measurement?

The fifty-third Congress of the United States, in 1894, passed a law that establishes and defines (1) the ohm as the unit of resistance; (2) the ampere as the unit of current; (3) the volt as the unit of electro-motive force; (4) the farad as the unit of capacity; (5) the coulomb as the unit of quantity: (6) the Joule as the unit of work; (7) the Watt as the unit of power; (8) the Henry as the unit of induction.

Do these names have any historical significance?

Yes. They honor the memories of George Simon Ohm, of Cologne, Germany, who discovered the law of electric currents, in 1827; of Andre Ampere, of Paris, who applied the term electro-dynamics to his discoveries in 1826; of Alessandro Volta, of Italy, who invented the Voltaic pile in 1792, of Charles Augustin de Coulomb, of Paris, who invented the Torsion Balance about 1779; of Michael Faraday, the great English experimenter; of James P. Joule, of England, one of the founders of the theory of the correlation of forces; of James Watt, inventor of the steam engine; and, finally, of Professor Joseph Henry, of Princeton College, New Jersey, who invented the first electrical engine or machine, and died in 1878. After concluding this chapter, you would do well to return and review these two paragraphs.

Can these measures be clearly and briefly defined in common language?

No. Excepting that the coulomb, or unit of quantity, is legally declared to be the quantity of electricity transferred by a current of one ampere in one second of time.

Proceed now to the useful features of the Electric Age.

The first and perhaps the most important invention was the Electric Telegraph. Benjamin Franklin sent a kite into the skies and obtained the electric spark from the key at the end of the wet string immediately after a thunder-clap. It was thus shown that Electricity acted through the wet kite-string. Franklin's discovery created a sensation at Paris, where he had many political and scientific friends and admirers.

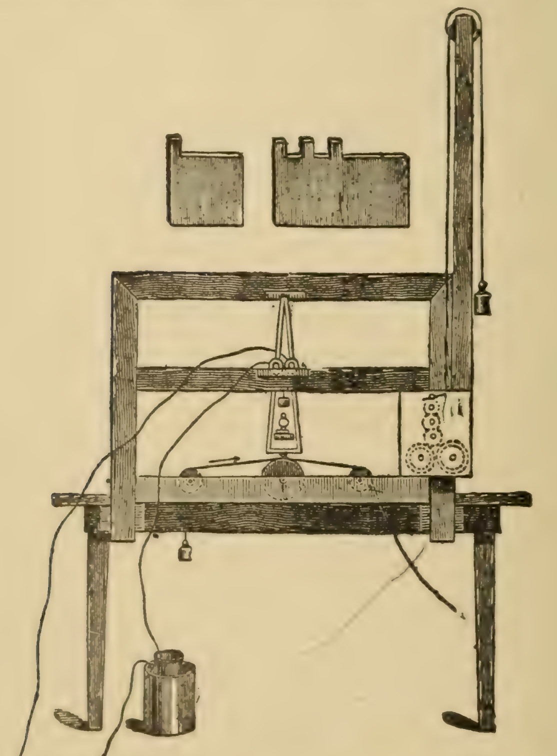


Fig. 1. MORSE'S FIRST TELEGRAPH.

Who was Morse?

Samuel Finley Breece Morse was a portrait-painter, and President of the New York National Academy. But at Yale College he had attended the scientific lectures of Professor Silliman, who had been sent to Europe by the Puritans to learn science without departing from the colonial religion. Morse was returning from Europe a second time when he heard on shipboard that the scientists of Paris "had sent a spark of Electricity through a wire from magnet to magnet." It is said that, on hearing this news, and understanding that the armature of the magnet could be pulled back and forth across the space where the spark leaped, Morse went into his stateroom and invented the telegraphic "key" or lever and dot-dash-space system of signals by which the world for fifty years transmitted its news.

What did Morse do next?

Arriving in New York he made his machines,—for the dots and dashes were to be impressed on strips of paper, as it was not then known that the human ear could readily understand their significance. Men of middle-age can recall the strips of paper at the railroad stations where the telegraph was first used. These strips were like those now used for the "ticker." Morse secured for a business partner, Ezra Cornell, founder of Cornell University, and Congress appropriated forty thousand dollars for the experiments. With this money a wire was strung from Washington to Baltimore. The first message was sent May 1, 1843, and the machine, as well as the strip of paper on which the first message was impressed, was exhibited in the east gallery of the Electricity Building at the World's Fair of 1893. The tape and clock train were abandoned in practical work as early as 1864. In 1858, a Congress of European Commissioners presented Professor Morse with a purse of eighty thousand dollars. The great inventor died in 1872.

What was the next important development of the Telegraph?

The Atlantic Ocean cable, laid in 1857, which broke almost immediately, was the work of Cyrus Field, who subsequently became the chief promoter of this form of enterprise. There was no ocean cable during the civil war in America. The first

success was attained in 1866, and afterward, with John Pender, of London, Field laid cables all over the world, and acquired an enormous fortune, which was seriously impaired late in his life. He died in 1895, and John Pender in 1896.

How are Electric Ocean Cables made?

In various ways. By Professor William Thomson's improved method, the core is a strand of fine copper wires, say seven in number, which are themselves made sticky with tar, resin and gutta percha. This core is then wrapped by several coatings of gutta percha, generally four. In applying the first coating care is taken to exclude bubbles of air, as these would work to the surface in the deep sea, puncturing the strongest cable. After the four coatings, the cable is stored in a tank of water and tested with currents of Electricity. It is then wrapped with tarred jute, or yarn, or hemp—called the "soft bed" for the sheath. Soft iron sheathing wires, themselves covered with two servings of tarred canvas tape or tarred hemp, are now twisted on the cable. All these twistings and envelopings are done by machinery.

How is the cable paid into ship?

It goes into a steel tank with a cone in the centre. Each layer of cable, called a "flake," is covered with boards. The cable goes out of ship over a "bow-sheave," and a dynamometer registers the amount of tension on the cable. When the cable breaks, the ship sinks a grapnel to the bottom and drags the bottom until the dynamometer shows that the thing pulling is a cable and not a rock or ooze. The North Atlantic has eleven cables lying on its bottom. Africa is surrounded. The 120,000 miles of cable in operation in 1897 had cost $200,000,000. One hundred thousand miles of additional cable have been laid in later years. The steamship Great Eastern laid the first one. The "open door" in the Orient, the acquisition of the Philippines, one of the Samoas, and Guam by the United States accelerated the cable-laying. The completion of the Panama Canal gives still another impetus to submarine telegraphy, and the names of Morse and Cyrus Field grow larger in the histories.

How are cable messages read?

The mirror-apparatus described and illustrated in earlier editions of THE FIRESIDE UNIVERSITY is generally giving place to Lord Kelvin's siphon instrument, with important improvements by Dr. Muirhead, and simplifications by Taylor, Dearlove, Brown, and other ingenius inventors. By the mirror-apparatus the movement of a pointer in one direction meant a Morse dot, and in the reverse direction it meant a Morse dash. By means of the siphon (sort of fountain-pen) idea, now in use, a pen using ink marks a tape or cylinder that travels under its point. The pen may be attracted to either side by magnets, and a wavy line is thus left on the paper beneath. The line waves one way to mean Morse dots and the other way to mean Morse dashes. At first it was necessary to electrify the ink, but as this made trouble in hot countries and seasons, a vibratory force has been invented and substituted for the ink electrification. By means of the new method, more than 600 letters a minute can be sent across the ocean. Dr. Muirhead's machine is a complex structure of Ruhmkorff coil (see page 96) magnets, vibrators, screws, pinions, bridge-piece, ink-box, tape-wheel or cylinder, etc. In an ocean cable the electrician or telegrapher meets with a resistance in the conductor (cable) that obviously cannot reside in the shorter land lines. The impulse of an ordinary Morse dot, passing along 3000 miles of copper wire would slow out into a Morse dash, and a Morse dash would stretch out so long that expensive spaces of time would be consumed in a short message. Accordingly the entire cable is made very nearly or quite electrostatic, and very sensitive indicators at the receiving end mark the obverse and reverse pulsations of a feeble or highly etheric force that may operate unhindered through the metallic molecules—just as a small messenger boy pushes his way most swiftly through a dense crowd of people.

Did Morse invent the word Telegraph?

No. The telegraph was in use in Europe during the time of Louis XIV., and St. Simon speaks of it. Signals were sent by semaphore, but could only be operated in good weather.

What improvements have been made in the art of Telegraphy?

We may mention the multiplex system, by which many messages are sent on the same wire at the same time, the "Wall Street Ticker," the recent improvements on the original ticker, by which all sorts of news are delivered to the subscriber in legibly printed form, with wide lines, and the still more recent Rogers Synchronous wheel.

What is Multiplex?

A telegraph wire runs, say, from Chicago to St. Louis. At each end of the wire branches are run to various receiving instruments, Pairs of vibrators (buzzers), opening and closing the lines with great rapidity, are going at each pair of end keys —that is, branch No. 1 at Chicago, has a vibrator going that acts ("sings") in exactly the same time (and tone) with branch No. 1 at St. Louis. The vibrators for branch No. 2 are alike, but different in time from those of No. 1. If we suppose that the current in the wire acts like waves on the water, then we may understand that we could start all sorts of waves in the water, some on top of the others. The instrument set to record the little waves will hear only those. That is, the current is a set of the smallest waves that go over the wire. So when a signal is sent through these little waves, only the operator with the instrument set for little waves hears it. His instrument does not act for any of the other waves that are passing in the main wire. So far as he knows, there is only one message on the wire, and that is the one he is receiving. Edison discovered and first worked on this principle.

What is the history of the Stock Ticker?

It was called Law's Gold Indicator, when it was brought out in Wall street, to publish the latest quotations for gold on the Exchange—for from 1862 until 1879 gold was at a premium over "greenbacks" in America. The Ticker is still used, under a large glass bulb. The subscriber pays so much rent, and the inspector brings rolls of paper tape and keeps the inking ribbon in order. The type-writing machine, with its ribbon, is a direct outgrowth of this invention. The wheel or wheels on which the

type are carried are operated by electric currents, and a weight and apparatus which is now self-winding gives the printing force to the instrument. Colahan, Phelps and others improved this very useful machine, which carries the market-prices of staples and securities all over the United States. The Exchanges of other nations have always been without this convenience.

What is the Rogers Synchronous Wheel, or "Telepost?"

It is an invention, first put in operation by the United States Postal Printing Telegraph Company. First the message

Fig. 4. ROGERS' TYPEWRITER PREPARING TAPE.

is printed on a Rogers Typewriter, which prepares or perforates

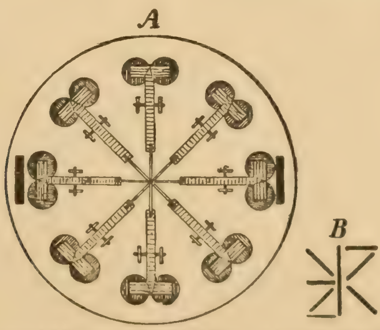


Fig 5. *A* VIEW OF TYPEARMS. *B* TYPE MAGNIFIED.

a tape. This tape is then put on the Synchronous Wheel, and a wheel at the other end of the line reproduces the tape. The Synchronous Wheel operates on the principle of Gally's automatic wind music, the perforated paper serving as a guide for the eight styluses that pass over the ribbon. The reproduction

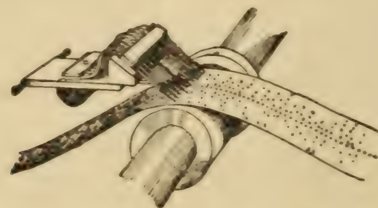


Fig. 6. TRANSMITTING THE DISPATCH.

of the message at the other end is automatic, and depends on the speed at which the wheels are run. One thousand words have been transmitted in a minute.

Is the Morse key still in use?

Yes. At the operating rooms of the great Exchanges, the political conventions, race-tracks, ball games, and outdoor sports generally, the Morse process is usually seen, although the receivers now-a-days use a type writer wherever convenient, and thus issue the message in a more legible form. Various cipher codes for shortening phrases are of course in use. Most Board of Trade and Stock Exchange firms, also, use their own cipher codes in sending and receiving dispatches. The Morse Telegraph remains, as it has been for sixty years or more, an essential element of commercial and financial operations.

How swiftly does Electricity act in the best mediums?

It is not known. The latest theories point to Life, Electricity, and Light as being extremely similar modes of Force, and Electricity and Light are supposed to travel with the same degree of speed—for instance, the Sun is eight minutes away. Practically, however, considerable time is needed to transfer messages over vast earth-distances. When the Pacific cable was finished, in 1902, 39 hours were spent in getting a message around

the world from Boston, Mass. It returned somewhat garbled in text, the word "around" arriving as "aruomd."

All that you have described so far is accomplished without a steam engine or other power?

Yes. Only batteries made of jars of water and acids with plates of metal are needed. The decomposition of the metals

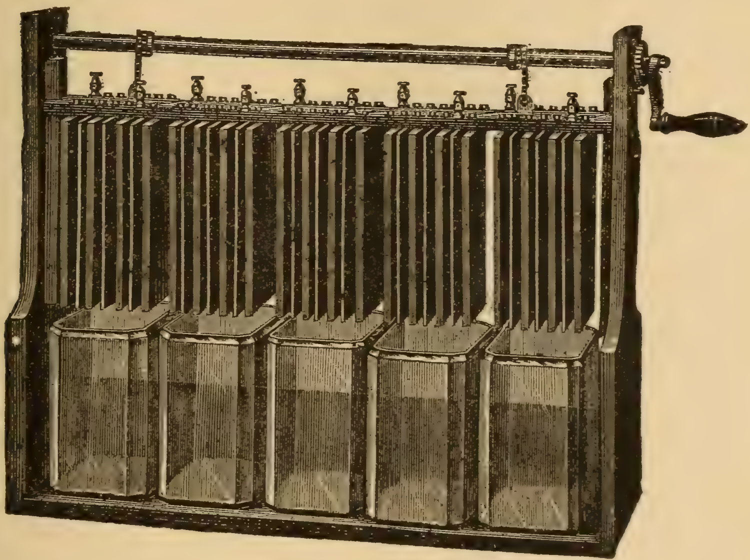


Fig. 7. BATTERY.

and water sets up currents of Electricity in the wires that run out of and into the batteries. Dynamos have lately come into use, however.

What is the next most important triumph in Electricity?

The making of the Dynamo, through a study of the laws of Induction.

What is Induction?

If the force of Electricity be set at work in a certain conductor, it will often set up a line of action in a neighboring but not a connecting conductor. The needle of a mariner's com-

pass will turn at right angles to the direction of a current of Electricity, if brought within the field of Induction.

Why is Induction especially important in a popular sense?

Because it is a chief element in the success of the Dynamo. This machine was first made by Pixii. It was varied and improved by Ritchie, Saxton, Clark, Von Ettingshausen, Stohrer, Dove, Wheatstone—and finally by Siemens, Halske, Brush, Edison, Burgin, Crompton, Weston, Thomson, Houston, Westinghouse, Tesla and others. If a wire or conductor moves across a Magnetic Field, a current of Electricity passes through the wire.

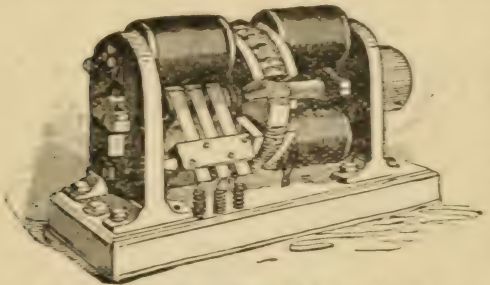


Fig. 8. FIRST BRUSH ARC DYNAMO 1877.

What is a Magnet?

The Magnet that man first found was an iron ore called the lode-stone—the protoxide of iron. The Greeks mined it in the region called Magnesia, hence the name of Magnet. It would attract pieces of iron, etc., if they came within a certain distance. Within this distance was called the Magnetic Field. Upon your understanding of the existence and importance of this Magnetic Field depends the entire value of this chapter, for the very principle of modern Electricity lies in the making of Magnetic Fields and the rapid pushing of circuits of wire through those Fields.

What was the first great use to which this loadstone was put?

It was used to point north and south in the Red and Mediterranean Seas. The Arabs introduced the mariner's compass into Spain, and thus the great ocean voyages of Vasco, Columbus and Magellan became possible. On the way to an understanding of the Dynamo, let us note that every Magnet has a north and a south end or pole. The north end will repel the

north end of another Magnet, and attract the south end. The Magnet is bent into the form of a horse-shoe merely in order to get the attractive effect of both poles at once. A straight Magnet is just as much of a Magnet.

What important thing is first to be said of the Magnetic Field of a Magnet?

Lines of Force circulate in it, and through the Magnet. If we lay a straight Magnet flat on a table, lay a sheet of paper on the Magnet, a sheet of glass on the paper, and sprinkle fine iron filings from a pepper-box evenly over the glass, and gently tap the glass while sprinkling the filings, they will arrange themselves along the Lines of Force of that Magnet. Many circular lines will be formed, of which the Magnet-bar itself is the diameter, while other lines will radiate from each pole. It is supposed that the molecules within the bar of steel (the Magnet) arrange themselves in order, like the filings, wherever a Line of Force traverses the bar. Faraday made a wonderful study of these Lines of Force. The Magnetic Field is the most important thing that is yet known of Electricity. More Electricity can be gathered by mere Induction to unconnected wires than can be gathered by any sort of rubbing or friction. Remember that it is not ordinary friction that causes the currents of Electricity that move with so much power nowadays. Metals are merely moved with great swiftness and frequency near other metals, the second ones having been previously magnetized.

How did the electricians improve the ordinary steel magnet?

They invented the Electro-Magnet, which is a rod or bar of soft iron wound with small wrapped wire. Through this little helical wire a current of electricity is sent, when the bar of soft iron within becomes a powerful Magnet, setting up strong Lines of Force, but ceasing to act as a Magnet as soon as the current ceases in the little wire. The Electro-Magnet was invented seventy years ago. Prof. Oersted, of Copenhagen, had discovered that the magnetic needle would turn at right angles to the direction of a current in a wire, if brought within the Magnetic field.

Proceed to the Dynamo.

We now have our Electro-Magnet, with its Magnetic Field, in which Lines of Force, like X rays, are playing, and piercing matter as easily as air. We say "playing" and "piercing," though it is not known that the lines move. We opine that Induction is the result of Lines of Force—that is, if one wire without a current receive a current from a parallel charged wire, the Lines of Force were set up in little circles, whose circumferences touched the two wires, and set their molecules in line crosswise of the wires. We now come to the wire or wires which are themselves to be set in motion in the Magnetic Field, so that currents will be set up in those moving (rotating) wires.

First describe the simplest Dynamo that could be made?

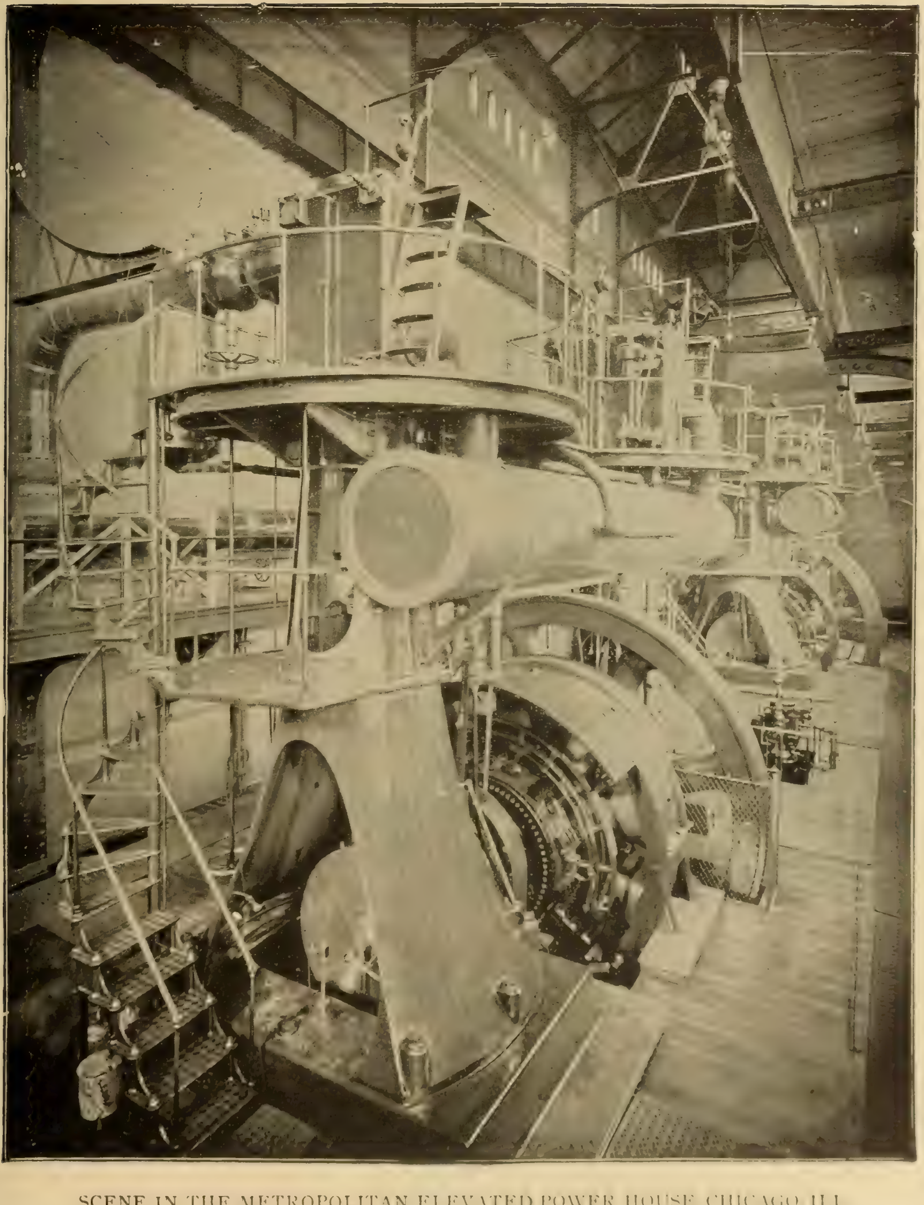
We would set the north pole of any Magnet before us. We would fit a yard or two of wire together at the ends (making a hoop) for a "closed circuit." We would take hold of the wire with both hands, stretching a couple of feet of the wire out straight. We would lower our two hands past the north pole of the Magnet, not touching it, the wire stretching from hand to hand, and the pole being at one time between the hands, and a current would pass around the wire in one direction. We would lift the wire up past the Magnet again, and a current would pass over the wire in the opposite direction.

How can we increase the power of this Dynamo?

In three ways. First, by making a stronger Magnet; second, by increasing the number of wires passed before the Magnet; third, by passing the wire faster. And this is the principle of the machines which send power to-day over such vast areas of territory.

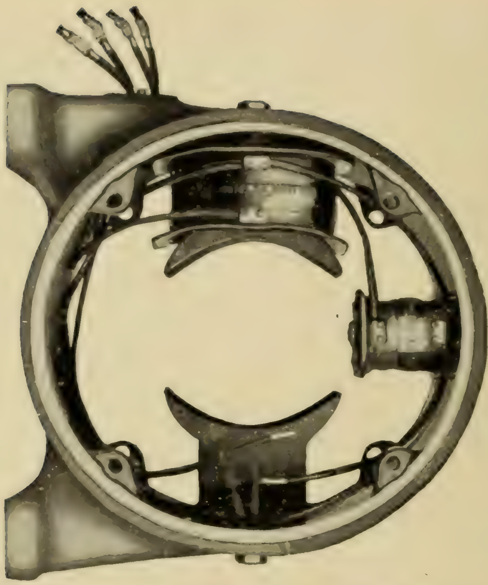
What is Armature?

It is armor. The word was first used to describe what is now called the "keeper"—the bar of iron which, when put on the poles of a horse-shoe Magnet, would hold the magnetism in the "horse-shoe." Next, it was applied to any bar that moved back and forth from the poles of the Magnet. Now it is applied to the built-up shaft (see Figs. 11 and 12) which revolves on the

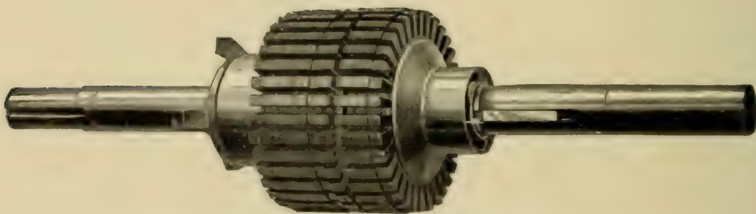


SCENE IN THE METROPOLITAN ELEVATED POWER HOUSE, CHICAGO, ILL

800 and 1500 Kilowatt Direct Driven Railway Generators.



FIELD FRAME OF DIRECT CURRENT MOTOR, SHOWING MAIN POLES AND COMMUTATING POLE, WITH ONE MAIN AND ONE COMMUTATING FIELD COIL IN PLACE.



ARMATURE CORE OF DIRECT CURRENT MOTOR.

COMPLETE ARMATURE AND COMMUTATOR OF DIRECT CURRENT MOTOR.

great Dynamos inside their many (multipolar) Magnetic Fields. Let us suppose a belt coming from a steam engine to this shaft, and acting on a small wheel so that the shaft will go very swiftly.

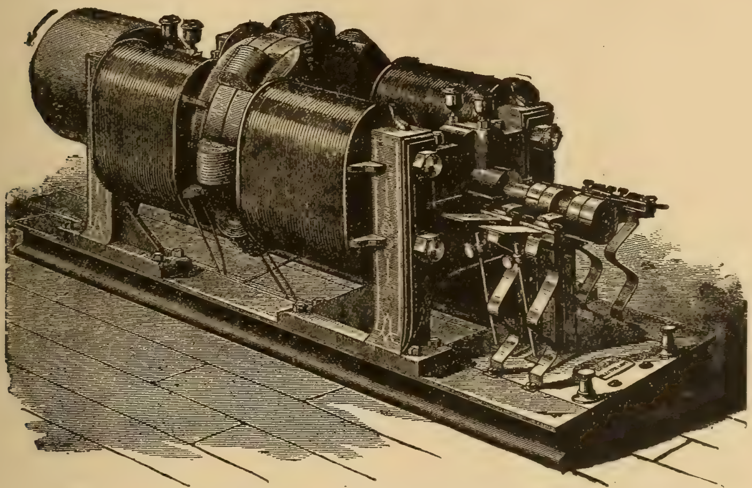


Fig. 9. 16 LIGHT, 2000 CANDLE POWER. BRUSH ARC DYNAMO. USED FOURTEEN YEARS.

Next let us see how the shaft is built up. The Laminated Core is first built. On the slim steel shaft is put a heavy cast-iron disk, in which are bolt-holes. Then a mica-disk is strung on; then a thin sheet-iron disk; then mica again, and thin sheet iron again, until at last a second heavy cast-iron plate finishes. Then these disks are bolted together and the whole shaft turned smooth in a lathe. This is done to secure a cool shaft, or it would set up so many currents of its own that it would burn out. (See Figs. 11 and 12.)

What come next?

The wires—just as we passed the wire in the Magnetic Field before the Magnet—are now to be passed, only with extraordinary speed and in great numbers. They are cut in pieces as long as the set of disks, and each heavy wire is covered with some

body of matter that does not readily carry Electricity. As the Roman bundle of sticks could not be broken when bound together, so the union of all these short wires increases their

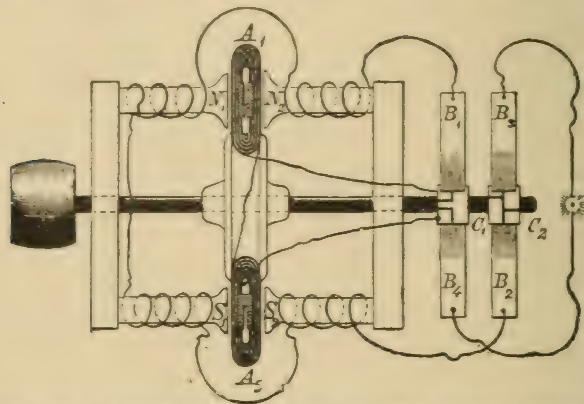


FIG. 10. DIAGRAM TO ILLUSTRATE THE THEORY OF THE BRUSH DYNAMO.

The bobbins *A1* and *A5* are two opposite coils, connected to a slit collar. Each pair of opposite coils is similarly connected with its own collar, and all the collars are grouped in two sets, forming the commutators *C1*, *C2*; *A1* and *A5* are connected with the first collar, *A3* and *A7* with the second, *A2* and *A6* with the third, and *A4* and *A8* with the fourth. The collars *1* and *2* form the first, and the collars *3* and *4* the second commutator. The upper brush of the first and the lower of the second commutator lead to the arms of magnets, the others to the outer circuit. When the bobbins *A1 A5* are passing between the poles of the magnets, the current passes as follows: Starting from the bobbin *A1*, it passes to *C1*, thence through the brush *B1*, to the electro magnets *N2*, *N1*, *S1*, *S2*, in order, and then back to *B2* and the commutator *C2*, thence through the brush *B3* to the external circuit for lighting or trolley, thence to *B4* and commutator *C1* to *A5* and back to *A1*.

magnetic power. It may well be called the Fasces of the Twentieth Century. The wires are bound on the shaft with bands of German silver. When the armature for the Dynamo for the Intra-mural Elevated Railroad at the World's Fair was built up, it was made so large and heavy that it was feared it could never be carried out of Jackson Park. Now, when this shaft of wires revolves in the powerful Field of an Electro-Magnet currents will pass back and forth through all these wires. But we do not want the currents to go in two ways. We do not want Alternating Currents. How, then, to Commute, to exchange the currents into one direction.

Explain the idea of the Commutator?

At the end of the shaft there must be an apparatus for catching the currents at the right time, and causing them to flow into the electric cable altogether. To describe this Commutator, let us imagine a simple Dynamo, made with one circuit of wire strung on a small shaft that revolves in front of a Magnet's pole. Each time the wires pass the pole they will reverse their current, yet the currents can be exchanged, or commuted into another wire, so that they will travel all in one direction. First, mount on the shaft a boss of hard wood. Next, mount on the wooden boss, the segments of a split tube of metal, which are to receive the current from the circuit of wire that revolves before the magnetic pole. These two segments do not enwrap the shaft, but leave spaces of wood between each other. Fixed away from the machine are immovable metal brushes, that rub the parts of the Commutator as it revolves, and an external coil of wire connects the two segments of the Commutator. As they revolve they take two currents at each revolution, but as the same one of two brushes always takes only every other current, the current in the external coil always goes the same way, although the current on the shaft Induced by the Magnetic Field is always alternating. The great cables which run along the streets of the city may be called the external coils of great Dynamos that are whirling ceaselessly through Magnetic Fields at the power-houses. (See Fig. 14.)

How are the Commutators on the great Dynamos arranged?

The Commutator here may be called the changeable connections of the moving wires on the shaft. This Commutator is made of pieces of copper insulated with mica. The brushes which rub on the copper commutator are strips of copper or pieces of carbon, and carry off the current at alternate times, as described in the simple Dynamo. There is no useful Dynamo that does not exhibit the three forms of (1) Magnetic Field, (2) shaft with Armature, (3) Commutator.

You said the Electro-Magnet that makes the Magnetic Field had to have a current going ROUND IT *before it would make a Field. How is that done?*

It is called Exciting. First, it was accomplished by a separate battery of Electricity. Now Dynamos are made into and called Self-Exciters. The Armature on the shaft is connected with the wires that enwrap the Electro-Magnet. There is a feeble magnetism resident in the iron of the Magnet, and a feeble current sets up in the Armature when it first revolves; that feeble current goes into the Electro-Magnet, and soon the whole machine is going at full power, the current that enters the big cables being practically continuous.

Is some of the steam power lost?

Yes. To attract force into the electric cables power is lost. But the advantage lies in the facility with which the electricians can distribute and apply electric power when it has been secured. Power is only gained without effort when we unloose the storage batteries of nature, as in lighting a bed of coal, or engaging chemicals in decomposition. As soon as the steam ceases to push the piston, the Dynamo shaft ceases to revolve, and the cable on the street, or the trolley wire overhead ceases to be a "live" wire.

Tell me about Bigelow's demonstration?

In the autumn of 1891, Professor Frank H. Bigelow of Washington, D. C., announced the successful culmination of his labors to show scientifically that the Sun is a Magnet; that the Earth is a Dynamo, and generates Electricity by revolving in front of the Sun. Lagrange of Brussels, had conceived this theory.

We now have the big current of electricity in the cables running out of the power-house. Whither does it go?

It goes out by cable and returns through buried wires and by other means to the power-house and the Dynamo. In the old days of the electric telegraph, the operator sank his wire into the earth, and this completed a circuit with any person to whom he was signaling with his key. Whether a line of molecules arranges itself all the way through the earth, or not, we do not know. In the case of the trolley cars, when the trolley track is laid—and it is a very good one now-a-days—a thick copper wire

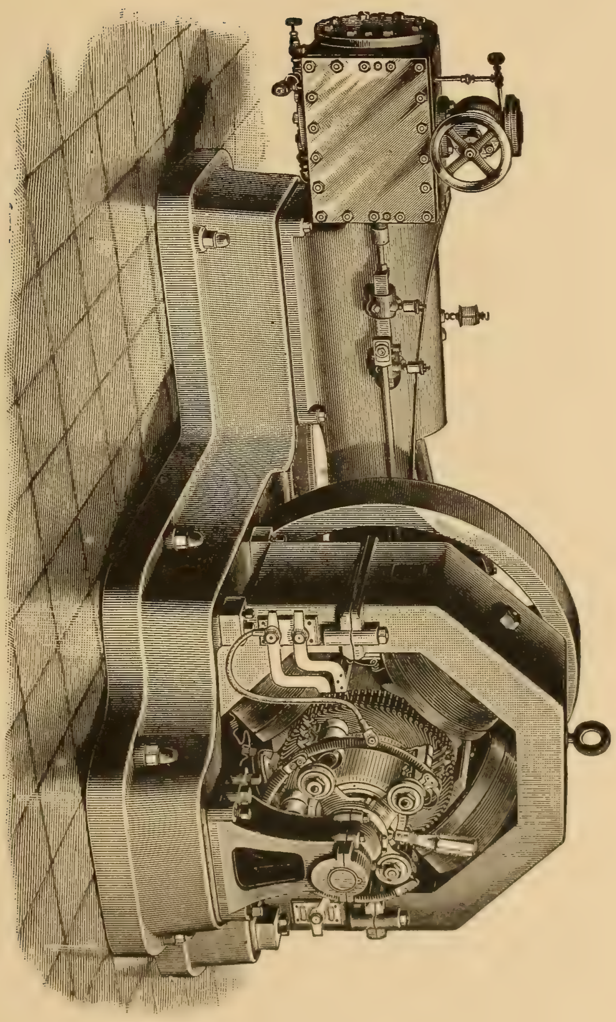


Fig. 15. MULTIPOLAR (MANY-POLES) DYNAMO.

is laid alongside one of the two track-rails. The current passes through the car-wheels into the rails, into the copper wire (into the earth also), and back to the Dynamo.

Now for the trolley cars. Why are they called trolleys?

In the old days a trolley was a skid, or railway truck. When the trolley was hung on an overhead wire, it was still called a trolley. The first application of Electricity to a surface car was through a trailing car or trolley that hung on a wire. The name was a natural outgrowth of the early conditions. Finally, a pole with a small wheel was pressed against the wire, and it was found that Electricity was so quick that it would come down the pole while the surface of the little wheel touched the wire. This pole is now the trolley-pole.

How does the current reach the car-wheels to make them go?

It comes down the pole to the power-switch, over the motorman's head. At the power-switch, power is taken off for light and heat in the car. Between the power-switch and the car-wheels are the lightning-arrester and other devices of a technical nature. A great number of wires are strung through the bottom of the car, in order to make the apparatus operable from either end of the car.

What is the Controller?

This is the metallic box standing upright at the left of the motorman. It is in fact a series of switches operated with two levers or handles. The little one stops or reverses the action of the Electricity. The big one has many notches at which the lever may stop, indicating various rates of speed or power of current. The car is stopped with a hand-brake, but the current may be reversed and the car forced backward by Electricity.

We have now reached the Motor. What is it?

The Motor is called the Electro-Motor by the electricians. We now come to a statement that must be wonderful to the inquiring mind. We have learned what a Dynamo is. Therefore, take note: "If a Dynamo," says Maycock, "instead of being driven by an engine, and used to *give* a current, has a current from a separate source (as from another Dynamo), passed

through it, its Armature will revolve, and the Dynamo will become an electric engine, capable of driving machinery." We saw that the Armature was the built-up shaft of plates and wires

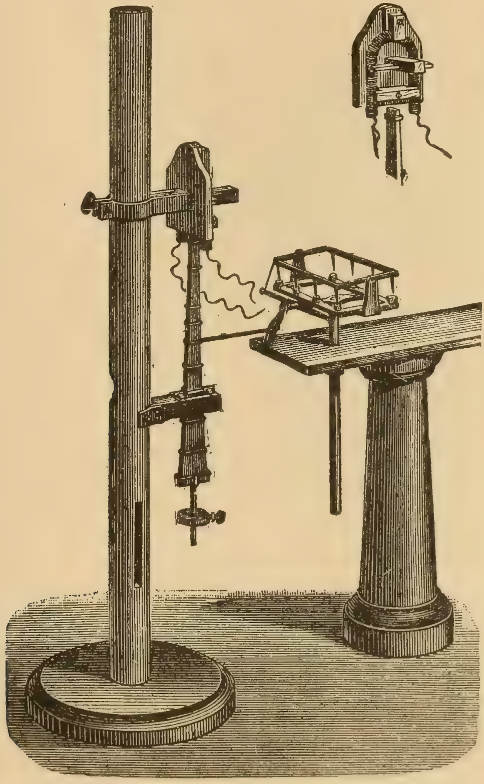


Fig. 16. NEGRO'S FIRST ELECTRO-MOTOR.

that revolved between the poles of the great Magnets. So if we connected still another Dynamo to this great Magnet, sending the Electricity into the great Magnet, we could take the steam engine's power off this built-up shaft, and it would go alone. Accordingly, under the street-car is a Dynamo (that is, a Motor), only it is to be run backward—reversed.

Where is this Motor?

The built-up Armature with its surrounding Magnet is not on the shaft of the car-wheels, because it whirls very much faster than the car-wheels. The Armature is on a shaft of its own;

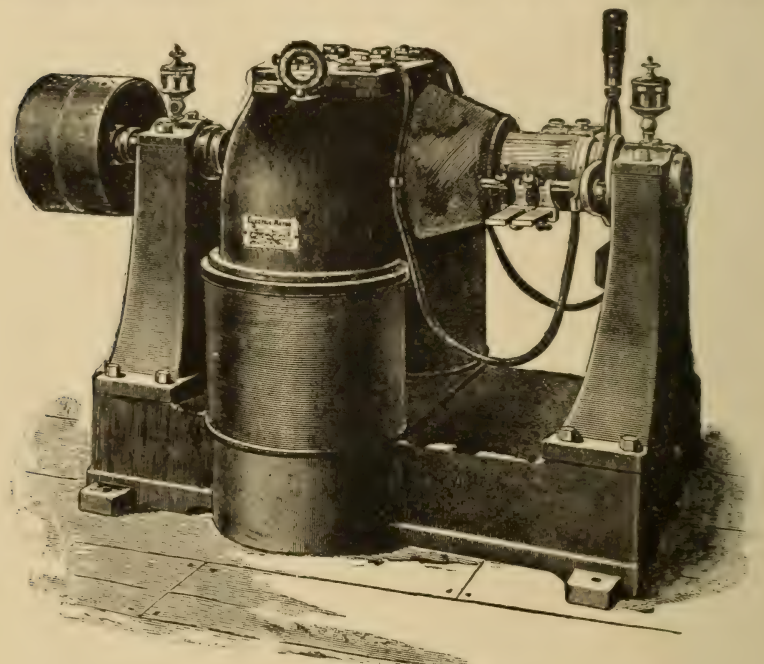
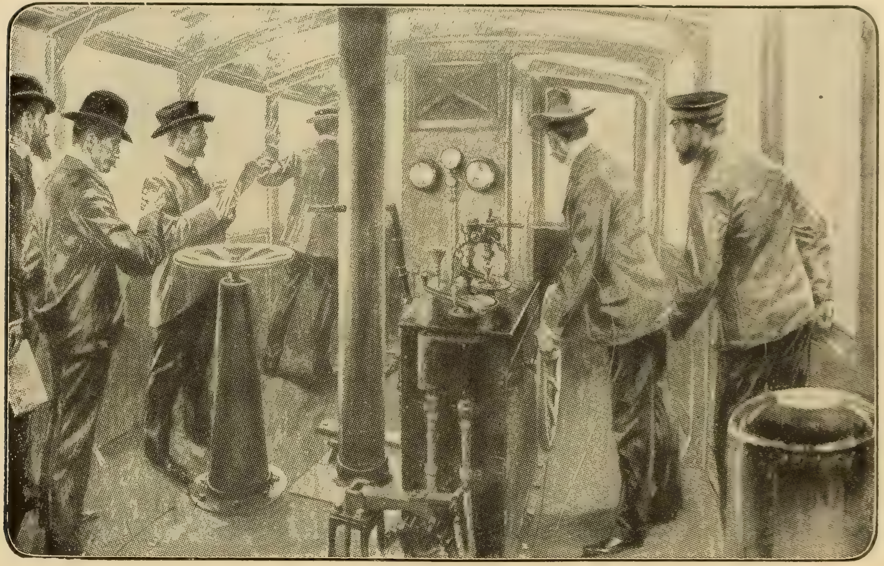


Fig. 17. STATIONARY MOTOR.

which rests against springs. On this shaft is a little cog-wheel. Of course the little cog-wheel, going so very fast—so fast, that you hear it hum from your car-seat above it,—plays into a sort of clock-work train, and gains all the advantage of leverage in acting on the car-wheel. The springs on the Armature-shaft are there to take up the sudden jerk with which the Armature would elsewise begin its work when the current from the trolley-wire should be sent through the Magnet.

Explain the uses of the wires in the street?

Running from the Dynamo in the power-house are great electric cables, covered with insulating material. At about every



FASTEST ELECTRIC LOCOMOTIVE IN THE WORLD.

This picture shows the interior of an electric railway carriage, the engine of which has attained the world's highest record for speed. During the trials on the experimental electric line on the German military railway between Marienfeld and Zossen, Germany, it flew over the rails at the rate of 130 miles an hour. The mechanism of the engine is simple, and only one man is required to control it. Electricians and officials are seen watching the speed indicator and studying the air pressure. The mast in the center of the car supports the electrodes that take the current from the overhead wires

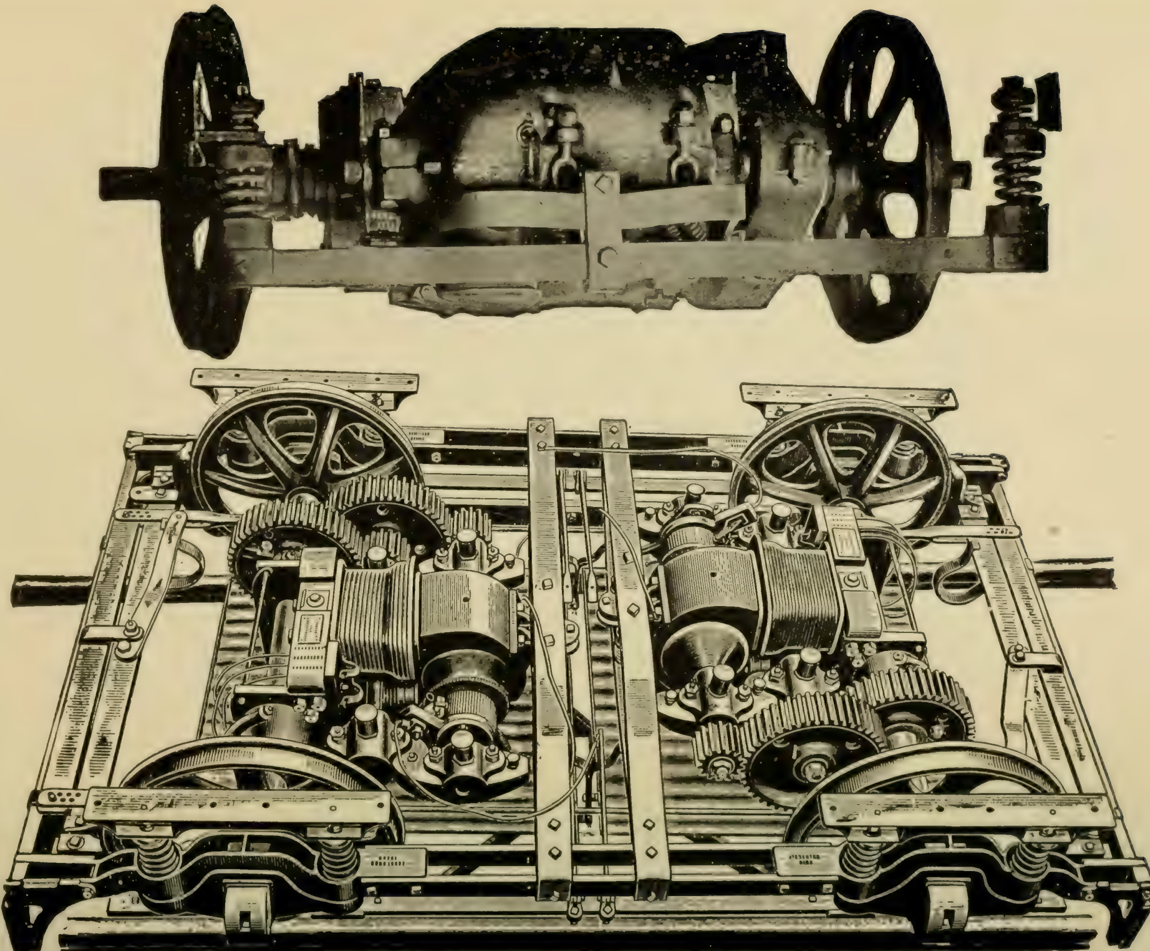


Fig. 19. THE ELECTRICAL MACHINERY WHICH PROPELS THE TROLLEY CAR. (Old and New)

eighth telegraph pole in the street, one of these cables is tapped, and the current seeks an outlet in the wire that runs across the street. Going across the street, the current finds the trolley-wire and greedily enters that.

What are the little wires for that form a net-work over the trolley-wires?

They are there only to protect telephone wires from falling on the trolley-wires and becoming "live wires," full of danger, from death and fire, to persons and property. In the early days of the "live wire," in an Eastern city on the Hudson River, a "live wire" fell on a horse and killed it. A man touched the horse and was killed, and a second man, striving to rescue the first man, was also killed. Beside all these wires, and the one that lies in the track, copper plates are buried deep in the ground at certain distances, and wires run to the plates. The earth itself gives a current from the plates back to the Dynamo in the power house.

How did the Electric Railroad Develop?

The trolley was first applied to heavier passenger traffic on the Intra-Mural Railroad at the World's Columbian Exposition of 1893. The electricity was carried in a third T rail, and the trolleys hung from the trucks of the motor car. The experiment was highly successful, and the Metropolitan Elevated Railroad of Chicago (practically extending to Aurora, Ill.), an electrical installation with a then-unrivaled power-house, followed. About ten years later the steam engines were taken off the New York City elevated lines. In the next decade the electrification of the New York Central terminal followed at the metropolis, and inter-urban railroads in many States adopted the "third rail."

What is the Electric Bridge?

It is the invention and design of William Scherzer, civil engineer, and the first installation was over the Chicago River, on the line of the Metropolitan Electric Elevated, here described. Mr. Scherzer patented his device December 26, 1896. The bridge opens in the middle and each side rises in the air to a vertical position, so that cars cannot run into the river when vessels are

passing. Each half of the bridge is a rocker, as if two rocking-chairs were tipped far back and together.

Tell Me About Thermometers.

In statements issuing from scientific laboratories, the use of the Centigrade thermometer is likely to be implied; in popular statements from Teutonic countries, the Réaumur; in popular statements of English-speaking origin, the Fahrenheit.

What Are Their Histories?

1. Dr. Fahrenheit's scale dates from about 1721. Distilled water at sea-level, with barometer 29.92, will boil at 212 on the scale of the Fahrenheit Mercury tube. The zero is an arbitrary point 32 degrees below the freezing point of the same water. There are thus 180 "degrees Fahrenheit" between freezing and boiling. 2. Linnæus, with the Mercury tube, made a scale of 0 at freezing and 100 at boiling water. This is called Centigrade. One degree Centigrade equals 1.8 degrees Fahrenheit. Dates from about 1742. 3. Reaumur's Mercury tube has 0 at freezing and 80 at boiling. One degree Reaumur equals 1¼ degrees Centigrade and 2¼ degrees Fahrenheit. Dates from about 1740.

Speak Further of High Temperatures.

The electric furnaces (see p. 241) as early as 1896 had generated heat as great as 3,500 Centigrade degrees. Fuel furnaces go as high as 1,800 degrees. The Calcium light reached 2,000. By Alumino-thermics the metallurgist has a method of securing 3,000 degrees instantly. A mixture of granulated Aluminum and Oxide of Iron is "set off" (see Catalysis, p. 291) by a mixture of Magnesium and Barium Peroxide; 3,000 degrees Centigrade are instantly generated. The preparation is known as "Thermit," and with it the continuous steel rail can be welded, the Thermit apparatus being portable and useful to a revolutionary extent. Prof. Goldschmidt of Essen, Germany, was the scientist to determine that, if vast energy were required to isolate Aluminum, then that energy might be retrieved through the means of chemical reaction. Any metallic oxide may be rendered pure by Alumi-

no-thermics, and thus the rare metals are both purified and cheapened. The oxyacetylene blowpipe produces a heat of 3,482 degrees Centigrade. Sir Andrew Noble, in a paper to the Royal Society, announced that, by exploding cordite in closed vessels with a resulting pressure of fifty tons to the square inch, he had generated 5,200 degrees Centigrade of heat. Moissan, when he began operations with his electric furnace, startled the scientific world with the announcement of 200 new substances and new methods, all secured by these super-heats.

I think I would like to understand something of "Potentials," "Accumulators," "Condensers" and more of Plus and Minus?

As to "Potential," we may define the word as meaning the power or action which a body is capable of putting forth. The electricians presuppose the earth itself to be a magnetized body, and any smaller body of matter is at zero when no electricity will either go into it out of the earth, or out of it into the earth, always allowing that the body is at rest. Its Potential is then zero. It is neither positive nor negative, for *positive* and *plus* are the same, and *negative* and *minus* are the same. Zero is also called the "electrical level." When a body has more electricity than zero—like the charged electric cable, it has a "Positive or Plus Potential Difference, of which it is trying to be rid. If, however, the body had less Electricity than the earth, it would have a Negative or Minus Potential Difference, and would be as active in taking up currents from the earth or elsewhere. Thus we have High Potentials. But the term "Low Potential" is customarily applied, not to a Minus Potential, but to a Plus or Positive Potential Difference that is not remarkably High—such as 25 volts as against 800 volts of pressure, or desire to get in or out of the earth. It is also true that if a body with, say 50 Minus come near a body with 100 Minus, the Potential Difference will be leveled. In the eagerness of earthly bodies to level the amount of their electrification lies the opportunity of man to make them perform labor for him, and save his body from an equal amount of toil.

How about thunderstorms?

The cloud may be Minus or Plus, and in the discharge of

Electricity the earth may either give or receive what is popularly called lightning. The photographs of lightning flashes usually show in which direction the stream of red-hot air is "flowing." Sometimes the stream has its gathering tributaries in the skies, sometimes near the ground. The law which we quoted as having passed Congress shows that these Potentials are measured, as well as the Resistance which bodies under varying circumstances offer to the entrance of the current.

What is a Condenser?

It is also called an Accumulator. It was once called Benjamin Franklin's Pane (of glass.) It is also the Leyden Jar. It is a device for increasing the electrical Capacity of a body or con-

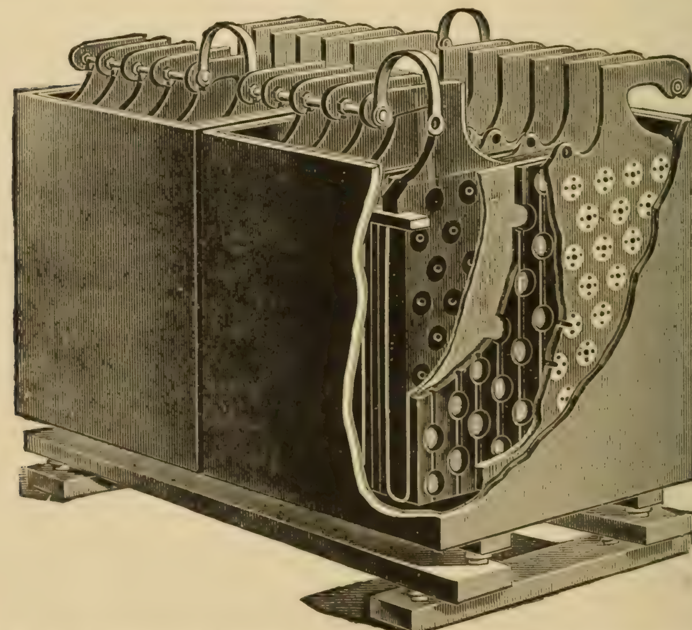


Fig. 20. THE CHLORIDE ACCUMULATOR, AS USED IN MODERN GREAT PLANTS.

ductor. To explain: If a sheet of tinfoil be hung by itself, it will require a certain amount of Electricity to render it Plus to a certain degree. But if the tin foil be put near another sheet

of tin foil, with a sheet of glass between them, and the second sheet wired into the earth, then the first tin foil sheet will require more Electricity to make it register the same Potential Difference as at first. In a word, it is the principle of Storage —a body giving off at a later day what it once took up.

Tell me about Galvani, Volta, the Voltaic Pile and the Galvanic or Voltaic Battery.

Galvani, while dissecting frogs on a table near a magnetic machine or apparatus, conveyed a current of force into a dead frog's leg, and the leg moved. Volta took up this experiment and learned the Potential Difference of metals. He made the Voltaic Pile, with a plate of zinc, a plate of copper, a woolen cloth wet with water, and many repetitions of this series of zinc, copper, cloth. This Voltaic Pile gave a slight shock. The zinc was *plus* and the copper *minus* and the current passed toward the copper. Now immerse this Pile in a trough of water and dilute the water with nitric, sulphuric, muriatic or other acid, connect the two outside plates each with a wire, bring the wires together, and a powerful shock results. The spark leaps across a small open interval, and the electric arc is seen. Sir Humphrey Davy used a thousand plates in the battery with which he produced the first good electric arc light. This Voltaic Battery—often called Galvanic, because Galvani opened the question—or its modifications, is usually the source of all the electrical power for the telegraph and telephone, the electric bell, burglar alarms, and other familiar devices by which a circuit is opened or shut.

To what recent industrial uses have Magnets been put?

At the rolling mills, magnets are now used for lifting great masses of hot iron, diminishing loss of life and limb, and personal inconvenience. Edison, in New Jersey, has succeeded in obtaining the iron from iron ore by crushing the ore and attracting the iron particles to magnets. Some of his pig iron thus obtained, it is said, is as malleable as wrought iron.

What is Electricity in the light of all that has been said here?

Electricity is a phenomenon to which man has not yet been able to attach a satisfactory working hypothesis. At present,

he thinks of it as if it were water, seeking its level. Without understanding it, the scientists have detected so many of its peculiarities that, after about seventy years of almost toyish experiment, it has now become in most cases, the most favored method of conveying power.

What are its present inconveniences and dangers?

These lie in the live wires and the cables that endanger life and property in the streets, or when put under the pavement, destroy the pipes that convey gas, water and other service.

How long ago were street-cars run by Electricity in a practical way?

About 1880, in Budapest. There the cables and trolley wire ran underground. About 900 patents, up to 1905, had been issued in the United States for underground conduits. Three conduit-roads had been financially successful—the one at Budapest made by the Siemens-Halske Company, one at Washington, D. C., and one at Blackpool, England, when the most notable installation of all, that of the General Electric Company, by which the Broadway cars are run in New York City, was undertaken. The electric "plow" enters the slot in the street from the motor-car above. This "plow" or "shoe" runs between a positive and a negative iron rail, and the Electricity goes up and sets the motor in operation. But the overhead system, particularly in the environs of large cities, and in the open country between towns, has given to the people a cheap and delightful method of riding, which works well, summer and winter, in all latitudes.

How is a car heated by Electricity?

A number of radiators are put under the car-seats, exactly as if they were for steam or hot-water. A wire leads from the power-switch, over the Motorman's head, to the radiator. When the current reaches the radiator, it goes into Resistance-wires, which are heated red-hot. The air of the car absorbs this heat, and the car becomes warm.

What is Resistance?

Whenever Electricity flows through a conductor or body, that conductor or body always becomes heated to a certain extent, because there is no substance that will allow Electricity to flow through it without offering *some* Resistance to its passage (see Maycock) and it is in overcoming this Resistance that the current develops heat. A big current in any little wire will heat or burn it, and a metal like german silver, offers great Resistance. Resistance is measured in ohms.

How are Potential Differences measured?

In volts. And current is measured in amperes. These three factors are always present in electrical action, and, by Ohm's Law, when any two factors are known, the other may be deduced.

Recite Ohm's Law.

The current equals the Potential difference, *divided* by the Resistance; again, the Resistance equals the Potential Difference, *divided* by the Current; or, again, the Potential Difference equals the Current, *multiplied* by the Resistance. This law was discovered in 1827, and has passed out of the realm of theory into the field of unquestioned fact, like other known laws of nature.

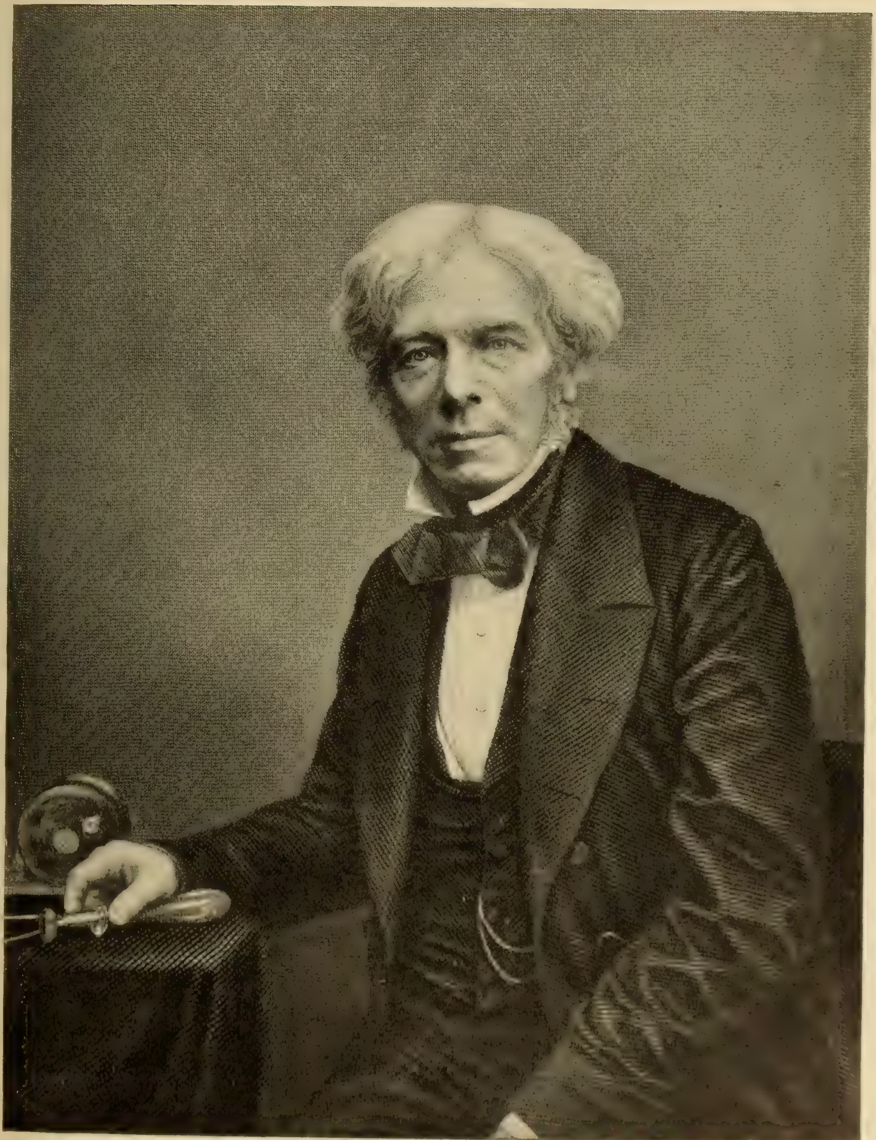
I think I could now understand some further statement regarding the measurement of Electricity.

We will quote Professor Elisha Gray—(see also page 22)—who says: "When a Current of Electricity flows through a conductor, the conductor resists its flow more or less according to the quality and size of the conductor. Silver and copper are good conductors. Silver is better than copper. Calling silver 100, copper will only be 73. If we have a mile of silver wire and a mile of iron wire and want the iron wire to carry as much Electricity as the silver and have the same battery for both, we will have to make the iron wire over seven times as large. That is, the area of a cross section of the iron wire must be over seven times that of the silver wire. But if we want to keep both wires the same size and still force the same amount of Current

through each, we must increase the pressure of the battery connected with the iron wire. We measure this pressure by a unit called the volt. The volt is the unit of pressure or Electro-Motive Force. The iron wire offers a Resistance that is about seven times greater than silver to the passage of the Current. The quality of the iron wire that prevents the same amount of Current from flowing through it as the silver is called its Resistance. The unit of Resistance is called the ohm, and the more ohms there are in a wire as compared with another, the more volts we have to put into the battery to get the same Current. The strength of current that flows through a conductor is measured by the ampere. The ampere is the unit of Current."

How are these units established?

We still quote from Professor Gray: "These units are established arbitrarily. The volt is the Potential or pressure of one cell of battery called a Standard Cell, made in a certain way. The Daniell Battery is about one volt. That is, the Electro-Motive Force of one cell of Daniell Battery is one volt. One ohm is the Resistance offered to the passage of a Current having one volt pressure by a column of mercury one millimeter in cross section and 106.2 centimeters in length. Ordinary iron telegraph wire measures about 13 ohms to the mile. Now connect our Standard Cell—one volt—through one ohm Resistance and we have a Current of one ampere. Unit Electro-Motive Force (volt) through unit Resistence (ohm) gives unit of Current (ampere). If we want to carry only a small Current for a long distance, we do not need to use large cells, but many of them. We increase the pressure or voltage by increasing the number of cells set up in series. If we have a wire of given length and Resistance and find we need 100 volts to force the right amount or strength of Current through it, and the Electromotive Force of the cells we are using is one volt each, it will require 100 cells. If we have a battery that has an Electro-Motive Force of two volts to the cell, as the storage battery has, fifty cells would answer. If we want a very strong Current of great volume, so to speak, for electric light or power, and use a galvanic battery we would have to have cells of large surface



MICHAEL FARADAY, F. R. S., D. C. L.

EDISON PERFECTING THE PHONOGRAPH.

and lower Resistance both inside and outside the cell. When Dynamos are used they are so constructed that a given number of revolutions per minute will give the right voltage. In fact, the Dynamo has to be built for the amount of Current that must be delivered through a given Resistance. The same holds good for a Dynamo as for a galvanic battery. If any one factor is a fixed one we must adapt the others to that one in order to get the result we want."

Why is a mention of Resistance especially important ?

Because all electrical operations in heating, cooking and lighting must be conducted on that line. All houses served with wires from a power-house may have radiators and cooking-ranges, and heat for such purposes is furnished in many of the great residences of the country. This heat has the advantage of being without odor, and making no ashes to empty, or dust to gather on furniture. It has the disadvantage, along with other so-called radiators of heat—that it cooks the same air over and over, and gives the room a "dead" and ill-ventilated feeling, which is rarely possible where there is a good fuel fire with chimney.

Describe the big Electric Light, such as hangs in the street in a large glass globe ?

It is served, like the trolley, from a Dynamo in a power-house. The cables usually run under the streets, in conduits built for them using Barrett's Chicago system. The wire running to the lamp is covered with rubber. The light itself is the flame discovered by Sir Humphrey Davy, and was for many decades a toy in the laboratory. It was an electric discharge, like a streak of lightning, from a Plus Potential to a Minus Potential, meeting with high resistance.

What was the Jablochkoff candle ?

It was the first form of carbon stick or candle to be used. It was a double candle, with a layer of Plaster of Paris between. It sputtered and acted discontinuously, and soon gave way to the modern apparatus, in which the upper candle is fed down

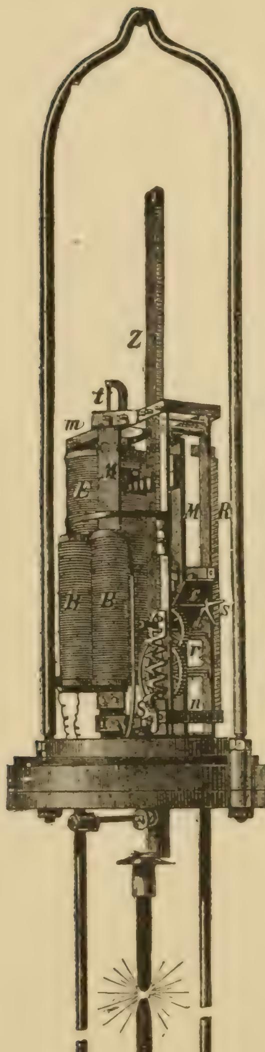


Fig. 21. ZIPERNOWSKY'S EARLY LAMP.

m n parallelogram; *m m*, lever resting on beams *M M*; *E*, solenoid; *z*, toothed rod holding carbon candle; *r*, clockwork; *c*, stopper for clockwork; *R*, spring; *s*, spur-wheel; *B B*, electro-magnet; *t*, piston inside solenoid.

to the lower candle by means of clockwork. The upper or Plus carbon burns twice as fast as the lower or Minus carbon. Particles of carbon are torn away from the upper candle, leaving a crater, and particles are deposited on the lower carbon making a point. It is thought that 85 per cent. of the light comes from the undetached particles of positive upper carbon; 10 per cent. from the undetached particles on the lower or negative carbon; and 5 per cent. from the flame, midway. About fifty volts of Potential are necessary, and ingeniously devised governing magnets at each lamp, allow just enough current to go through the candles, without robbing the other lamps on the same circuit.

How early was this Light used for practical purposes in America?

About 1882, when the Grand Pacific Hotel at Chicago, was lighted, and lamps were hung at Wabash, Indiana. The first central station was erected at San Francisco. Although the City of Chicago at last erected its own power-houses in several districts, nearly every small city was earlier lighted by the arc light, (as the carbon candle light is popularly called) before the streets of Chicago were thus illuminated, and in 1897 many

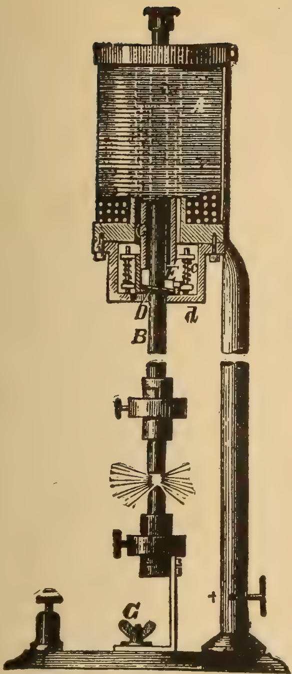


Fig. 22. THE BRUSH LIGHT.

Clockwork replaced by brake-ring. *A*, solenoid; *C*, wrought iron tube; *c*, spiral spring; *d*, adjusting screws; *B*, holder of the upper carbon; *G*, screw adjusting the lower carbon; *D*, ring for lifting hook.

hundred miles of streets were still lit and controlled by private gas companies, to the prejudice of popular convenience.

What great invention followed the introduction of the arc light in public places?

Edison divided the arc light into smaller lights, and the incandescent lamp became a feature of life in modern communities. Millions of the glass-bulb devices are sold each year in the United States, and large glass factories are kept busy the year round making the bulbs. When Edison was inventing this lamp, he found the chief part of his trouble was the shadow which the stem of the bulb threw directly beneath, and it was said at the time that it was only by accident that he happened to turn the lamp up-side down, and noticed that it made no difference in what way the instrument was held—it would burn equally well.

I see a thread of light in the bulb. How is that made?

It is caused by the Resistance which the filament or thread offers to the passage of Electricity. The thread is heated red-hot, and thus gives light. The air has been exhausted from the bulb, and thus the thread does not burn up, as does the carbon candle in the arc light. The current of Electricity comes to the lamp in the same way that the arc light and trolley car get their currents—that is from a Dynamo, although a single light may be made from a battery or jar.

What is the thread made of?

Fibres of bamboo, cotton, silk, or tamodine (a variety of cel-

luloid) were first used. The strips of fibre were bent in iron molds into the shape you see in the picture at 3. Then they were packed in carbon dust. This pack was put into a crucible of plumbago or black lead. The crucible was sealed air-tight and

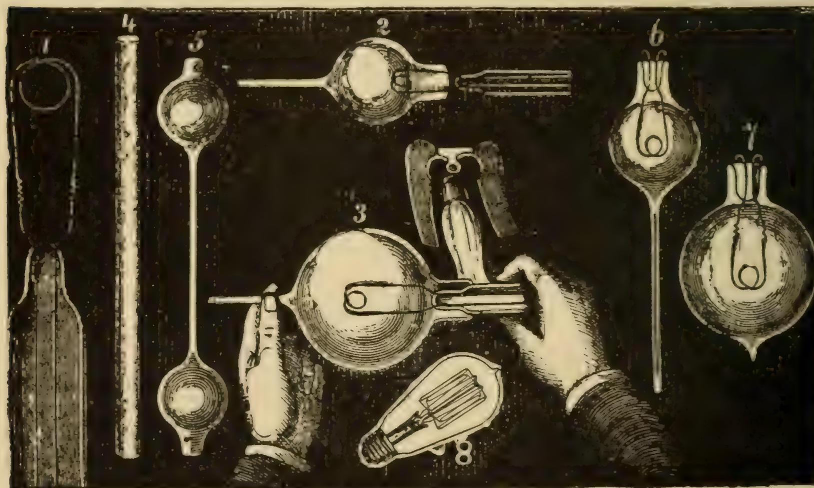


Fig. 23. STAGES IN THE MAKING OF INCANDESCENT LAMPS.

1. Glass "saddle," showing platinum wires, as first used by Edison. *4.* Tube out of which the bulbs (*5*) are blown. *2.* "Saddle" placed in a bulb. *3, 6, 7.* "Saddle" and bulb fused together and long tube fused off. *8.* A more modern tungsten or tantalum lamp, without need of platinum wires.

put in a hot-air furnace, where the crucible became white hot. In this way the filaments were charred, and also absorbed the Carbon, and, when they came out of the crucibles, they were so steel-like that they might be straightened, and would spring back into their original bent. For years Edison could deliver the current into the bulb only through Platinum wires, as Platinum expanded and contracted under heat in the same degree with glass, but, finally, Platinum was done away with, and that much economy secured. Next came the substitution of Tungsten, Tantalum, Osmium, etc., for the Carbon filaments. The Tantalum filament of the Siemens & Halske bulb is 20 inches in length, yet a pound of Tantalum will supply 20,000 lamps. The Tungsten bulb was at first very large.

Do women figure in the manufacture of these lamps?

Yes. It was found that they excelled in handling the filaments, and they have become glass-workers, for the conductors are fixed in a glass saddle and the filaments welded with glass to the conductors at a glass-blower's flame, and women perform this delicate feat with speed and accuracy. When the filament is properly wired in the bulb, that end is sealed air-tight, and is not again opened.

How then is the air extracted?

You have noted a sharp point on the outer end of the bulb as it points down toward you. When the bulb came from the glass factory where it was blown, an open tube protruded at this point. This tube is still on when the girl gets through with the wire-end of the lamp. The bulb now goes to the mercury exhaust-pump. The pump is connected with the end tube, and the air is nearly all taken out. The bulb meanwhile has been connected with electric wires, and a current is turned on. The filament lights up and aids in expelling the air. If everything is satisfactory, the glass-worker now seals the passage by fusing the tube while the air-pump is still connected, the fused tube is broken off, and the lamp is air tight, and is ready for the brass cap which finishes it for the market.

What has the Incandescent Light done?

Edison added new splendors to the night. Broadway in New York, State street in Chicago, etc., are themselves electric expositions, held once a day, free to all. Where bulbs were thought to be in profuse use when tens of thousands were lit, as at the earlier world's fairs, nowadays the count must be in hundreds of thousands. To obtain the highest value the bulb must be renewed often, as the inner obscuration from deposit of Carbon or other Element cannot be prevented. On the streets, sets of bulbs are lit in order.

I have noted these changing lights in city streets. How are these effects produced?

The machine which turns the lights off and on is like the cy-

linder of a hand-organ, and operates on that principle. When you see the lights ascending a column or traveling along a route, the appearance is illusory. Certain bulbs are lighted and extinguished by their own connections at a certain moment, which gives the impression of a traveling light. Thus a barrel may seem to turn, or a sphere to rotate, but both are stationary. When the operating cylinder has revolved once, it catches a pawl or key and lifts it. The moving of this key perfects an electrical connection. It is an automatic Switch-Board.

What is a switch?

Let us trace the word. It was first a twig, cut from a tree. Then it became a branch from a main trunk of railway. Next, probably the railroad men applied the term to the Switch line of wire on which the Morse telegraphic instrument would be stationed, for when the cumbrous mechanism was not in use it was not needed on the main wire. Accordingly, before the telegraph operator began work, he turned a little brass arm, which set the current of the main line running through his machine. This business of shifting weak currents of electricity, made by Voltaic Batteries, has grown until the Switch-Boards of the Western Union Telegraph Company, or the Power-House of a city electric railway system, cover a great surface and are marvels of complexity. The Switch-Board before which the telephone girl works is another example of convenience, and every theatre has a Switch-Board. The Switch-Boards at the World's Fair were studied with interest by the electricians of the world. It follows from the origin of the word, that any lever or key which breaks or restores a circuit—that is, cuts or completes a line of wire, is called a switch. The button of an electric bell, which when pressed, completes a circuit, by joining two metals together, is such a switch.

What other especial conveniences followed from Edison's invention?

All street-cars and elevated stations are lighted thoroughly and without labor. The movement of brilliantly lighted cars through the streets carries with it a constant illumination. Light may also be taken into subterranean places—cellars, tunnels

and the like,—where explosion would follow the ordinary means of lighting.

Was the Electric Light, as produced by the Dynamo, a scientific surprise?

I can best answer yes by quoting for you a paragraph in David A. Wells' book, "Things not Generally Known," edited by him in 1857. In this work, at page 302, is the following statement by Prof. Alfred Smee, F. R. S.: "There is one serious drawback against the use of Voltaic Electricity for the purpose of illumination, and that is its serious expense. It is a primary law of nature that no power can be obtained without a corresponding change of matter. In Voltaic batteries, the combination of zinc with the oxygen of water, constitutes the change of matter which gives rise to Electricity. As much dearer as zinc is than coal gas, so is the cost of the Voltaic Light over the ordinary mode of illumination. But the expense is even still greater, inasmuch as the equivalent of zinc is five times higher than that of carbon; and furthermore, carbon combines with two equivalents of oxygen to form carbonic acid. For this reason," continues Professor Smee, "the Electric Light will probably forever remain a pretty, scientific toy; unless, indeed, some person shall have the good fortune to discover a battery with a carbon positive pole." Professor Smee, who was an eminent electrician, lived until 1877, when the positive pole of the Dynamo's armature circuit had become fairly well known to scientists.

I Notice Tubes in which the Electric Light has been vastly extended.

Yes. That is the Cooper-Hewitt invention—a long distance away from the mere spark and Sir Humphrey Davy's arc of the long-ago. In the Cooper-Hewett light, the tube may be a very long one. It is filled with Mercury vapor, and the current of electricity passes through, as in a Crookes tube. There is no filament, so, of course, that much resistance, heat, wear, and obscuration are obviated. The cathode must be Mercury; the anode may be Iron or other metals. Upon setting up the current the tube is brilliantly illuminated from anode to cathode, but unfortunately for the general public, the shade of light cast is

greenish. However, the light has benefited the arts, illuminates lonely or little frequented places, and serves as an alluring advertisement.

What is the Electric Theatre?

This was displayed in the Electricity Building and on Midway Plaisance. It is, in brief, a summary exhibition of the lighting facilities of a modern theatrical stage. The scene chosen at the World's Fair was in Swiss Mountains. The night slowly set in, the light appeared in the windows, the stars came out, the day slowly dawned, the sunlight grew strong, a storm arose, with lightning and thunder, a rainbow appeared in the sky, the sunlight reappeared, the evening approached, darkness set in, and the stars again twinkled on the mountain's crest—all this to slow music and to delighted free audiences that had stood hours waiting for admission.

Describe some modern stage effects?

At the Auditorium Theatre, in Chicago, is one of the most complete installations in the world. The stage, 90 x 160 feet, has 1500 electric lights. There are 150 footlights in three rows, red, white and blue. At fourteen different places, electric connections can be made. In the "Black Crook," when Zamiel touches his thumb and forefinger together, there is an electric flash. In "Faust," when Mephistopheles draws his sword in a circle, it strikes an electrically charged wrought iron ring, and there is a vivid circle of fire. Flowers light up when Mephistopheles curses them.

Is there a Dynamo under the stage?

Yes. You may desire to know how the horizon and sky effects are produced. The rear scene of the stage will be a canvass about 40 feet square, such as is spread for a stereopticon lecture. Behind this rear canvass is a stereopticon, in which burns an electric arc light, or perhaps several stereopticons. Between the lens of the stereopticon and the electric light is a place where different machines may be introduced. Thus a glass disk, with clouds painted on it, when placed in this aperture and revolved before the light, throws great masses of pictured mist on the canvass. The lightning disk is revolved in another stereopticon,

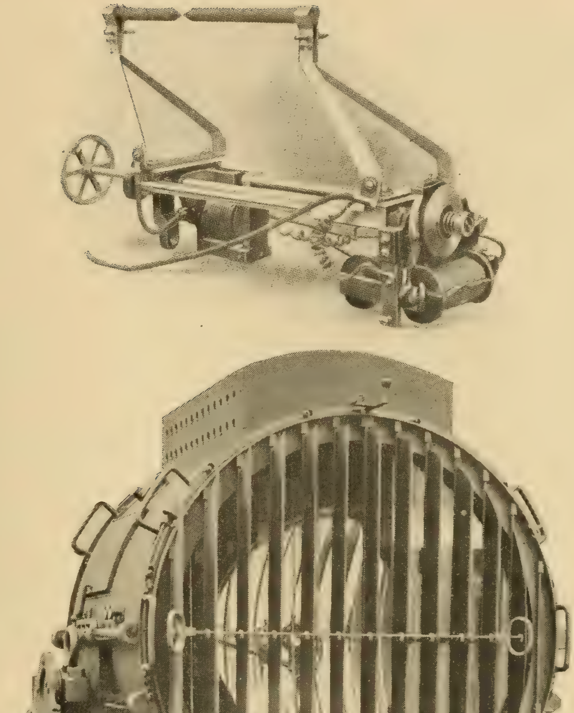


Fig. 25 THE SEARCHLIGHT AND ITS ELECTRIC ARC LIGHT

its flashes playing on the black storm clouds. Fire clouds, as in the "Huguenots" or other scenes of conflagration are painted in red, black and yellow and must be turned rapidly. For rain, hair-lines cross the disk in every direction. In the "Queen of Sheba," a caravan moves for countless miles on the desert horizon. Ripples on the water are produced by wavy black lines on the disk.

What is the stage rainbow?

It is made by holding a prism of glass before the lens of the stereopticon. A setting sun is a disk of ground glass behind which is an arc light. Glasses color the disk red, yellow, gray, and finally, as in "Tannhauser," night comes in full darkness. This machine hangs on a pulley. A stage fire-fly is a minute arc light, and the lower candle is set on a small spring. When the current is on, the candle rises, and a tiny flash is seen. The current is an interrupted one. The Star, Venus is simulated by cutting a hole in the canvas, placing a green jewel in the aperture, and lighting an incandescent lamp behind. A switchboard with fifty switches regulates the general lighting of the stage, and it is to the delicacy of the light gradations here made possible that the scene called the Electric Theatre, previously described, owes its success.

Name a few Electricians and Physicists (beside Roentgen and the Curies) who have received the Nobel Award.

This great prize (about $40,000) was given to Becquerel (see Index) in 1903; to Sir William Ramsey (see page 222) in 1905; to Lord Rayleigh (see page 218) in 1907; to Henri Moissan (see page 241) in 1906; to Sir William Crookes (see references in Index) in 1907; to Dr. Lippmann (see page 325) in 1908; to Marconi (see page 102) in 1909; to Prof. Ostwald in 1909; to Prof. Ohnes (see page 559) in 1913.

What did Prof. Ostwald do?

He made new discoveries in Catalysis (see page 291) of high commercial value, and invented the Catatype process in Photogra-

phy. He passed Ammonia over Platinum, and secured Nitric Acid without loss of Platinum, and in a large industrial way.

I have heard of Air-Separators.

Yes, between the heat-makers and the cold-makers, the scientists have learned that they can whirl the "cream" (Oxygen) off the Nitrogen in the air. First the cold-makers "boiled down" the Oxygen, when both gases were "frozen." Then the Mazza centrifugal-wheel, revolving as fast as 2,200 times a minute, whirled the Oxygen in ordinary air to the outside, and on feeding this "cream of air" to the fire, 27 per cent of coal was saved.

What is the Mercury Vapor Sign?

The sign is erected in a conspicuous and perhaps far-off place, with letters 10 feet or more high. Upon this sign a Mercury-vapor lamp reflects an emerald-green light. The sign "has the appearance of being painted on the clouds in phosphorescent paint."

What is the Quartz Tube?

The electric furnace made feasible the fusing of quartz for manufacture into vessels and tubes. Places not easily accessible, where previous lamp-breakage had been frequent, are now brilliantly lighted in the following way: The rare earths or metals are packed into a quartz tube (which is transparent) and it does not matter whether the contents "break" or not. The electric current is turned on, the rare earths or metals incandesce, and the mountain or the spire is lighted until the connecting wires and not the quartz breaks. We may expect to see quartz "bulbs" in our houses. The quartz tubes, too, were a lucky windfall to the chemists in their own laboratories, displacing glass.

What new Installation of Electricity and Lighting?

The elaborate system for the guidance of operators and navigators at the Panama Canal. The Darien Radio Station, also is or will be one of the largest wireless stations in the world, sending signals to San Francisco and Arlington, Va. Doubtless connection will be frequent or occasional with the Eiffel Tower at Paris.

What of the World Wireless?

Noon will be signaled from the Eiffel Tower. The American wireless now proceeds from San Francisco to Nome, Alaska, and across Bering Strait to Anadysk, in the country of the Tchuktchis, north of Khamschatka, in Siberia. Advance notice of the progress of hemispherical storms is now not infrequent.

How of the Recent Spread of Industrial Science?

Hydro-electro power-plants and smelting works have been erected on the island of New Caledonia (in the South Seas, a region made famous by the Paris Commune). Here Ferronickel and Ferrochrome are produced electrically by a French firm.

What is the Pyrometer?

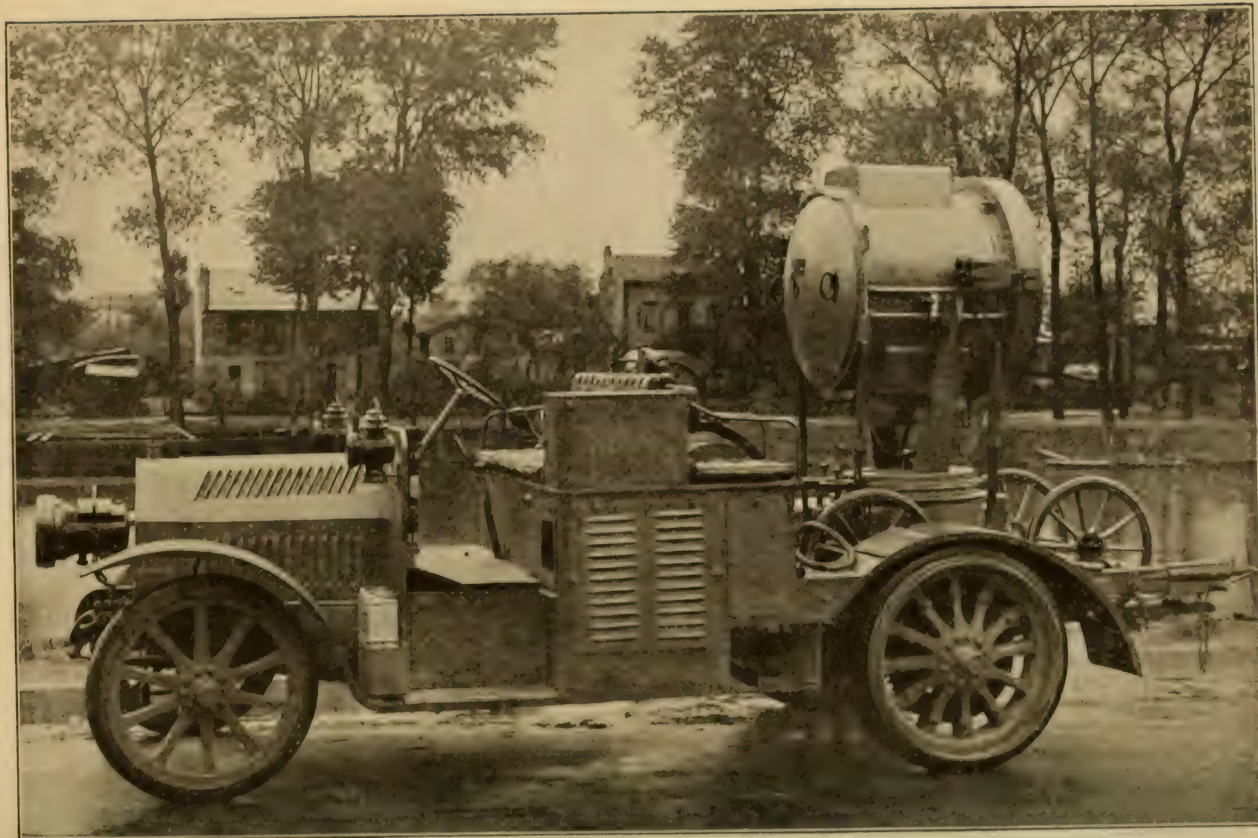
The various Instrument Companies (to meet the new conditions) have placed on the market improved types of thermo-electric gauges for measuring the temperatures of metals in their molten state. Prof. Shook, of the University of Illinois, has invented an improved optical pyrometer, with scale for furnace temperatures. (See pp. 42 and 242.)

What is the Walker Process?

By this plan, the United States Steel Corporation combines the Bessemer converter and the electric furnace. The metal decarbonized in the converter is recarburized in the ladle before the metal goes to the electric furnace.

To what astonishing use has the Arc-Light been put?

Lights and flames which project their rays to great distances have been the study of all lighthouse builders. Under the operations of the early reflectors of light, although the flame were sheltered and backed by brilliant reflectors, yet as the flame was a central point, and its rays went out in all directions, it followed that in the cone directly in front of this central point the rays that went past the outer lips of the reflector or holder diverged into the skv and downward into the water or earth. The appli-



THE NEW ARMY SEARCHLIGHT.

cation of the glass prism—that is a three-cornered bar of glass—to the work of reflection, while it corrected all the rays that reached it, and sent them all out in parallel lines ahead of the flame, so that they would travel to a great distance in the direction where they could be useful, still did not cover the case of the rays that went out past the rim of the reflector, on the way upward, downward and sidewise. So Fresnel, who had applied the prism adopted the ingenious plan of nearly surrounding his flame with prisms and mirrors, and letting out his rays only when they had been bent around so many times that if they went out at all they must go out straight, at an aperture just ahead of the flame.

Describe the great Search-Light?

It was shaped like a bass-drum, and hung by trunnions on a fork, so that if it were really a drum, the drum-head would look forward into the sky, or any direction desired. The apparatus weighed 6,000 pounds, yet could be easily turned in all ways. Inside at one of the drum-heads was placed a Mangin concave lens mirror sixty inches in diameter. This piece of glass was only one-sixteenth of an inch thick at the centre, but it was three and one-fourth inches thick around the edges. The glass weighed 800 pounds, and its besel or ring and rear cover 800 pounds more. This mirror formed the inside of the rear drum-head, and the front drum-head was made of strips of glass placed vertically, like the strips of a picket-fence.

What is polarized light?

When light goes through strips, it is supposed to cease to vibrate sidewise, as a rope would do if it crossed two picket-fences. Efforts to shake the rope sidewise would only give it an up and down motion—a polarized motion—between the two fences. This is to prevent sidewise vibration and dissipation as the shaft of light is shot out of the great light-mortar, for it is properly called a Projector. In the drum in front of the mirror sliding on ways on the bottom, was an Electric Arc-Light of 200 amperes, or twice and a half as much light as was used for one of the Electric Fountains. The carbon candles were coated with copper, and had soft cores that would make a deep crater

and high set off in burning. The crater of the upper candle was well exposed to the mirror, so that this most brilliant point in the light would be well condensed by the mirror, and its rays sent in parallel rays toward the front of the drum. In the engraving (Fig. 25) may be seen the apparatus for the arc light. The small reflector prevented the arc light from being seen from in front of the search light. That is between the glass strips and the arc light was a smaller reflector to catch the rays that went forward and throw them back into the big mirror where they would be straightened, or sent out in a forward line. When the Dynamo was at full speed, the arc-light was said to give 100,000 candle-power, and the mirrors, by collecting or condensing all its rays threw on the sixty inch disk of air immediately outside of the strips of glass a degree of illumination equal to the theoretical value of 375,000,000 sperm candles.

What was the effect?

When this Search-Light was directed upon distant clouds, it made its mark clear upon them. On top of the Woman's Magazine Building at the St. Louis World's Fair, it could be seen at Centralia, and people at Alton, north of St. Louis, could read by the aid of its light. The shaft passed through the air overhead, much like the tail of a great comet. A smaller light on Mount Washington, makes objects visible that are 100 miles away, and the Search-Lights now in New York harbor are seen fifty miles away. Signals are flashed on the clouds The Siemens-Halske Projector at the World's Fair was also an example of the triumph of modern optical science, in the economical use and concentration of light-rays.

Are there electrical meters like gas meters?

Yes. We illustrate Maxim's Meter, and there are countless forms and patents. (Fig. 26.)

What is a Solenoid?

A solenoid is defined as "an electro-dynamic spiral, having the conjunctive wire turned back along its axis, so as to neutralize that component of the effect of the current which is due to the length of the spiral, and reduce the whole effect to that of a series of equal and parallel circular currents."

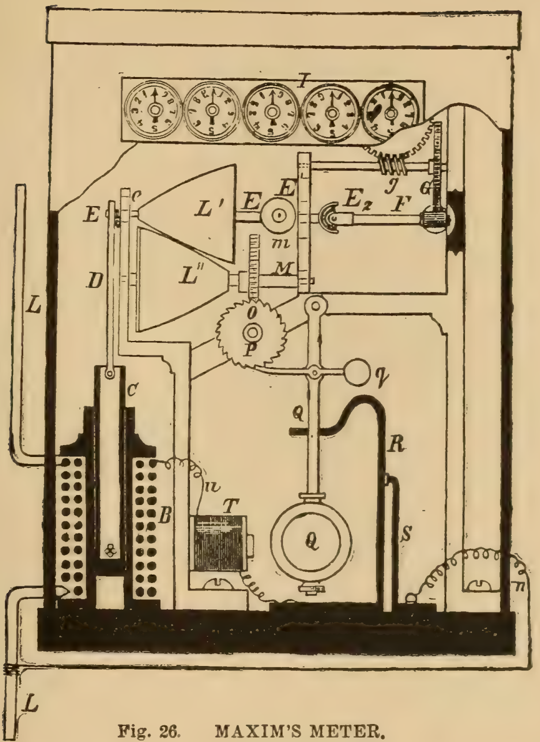


Fig. 26. MAXIM'S METER.

Fig. 26 represents an Electro-meter constructed by Maxim. The solenoid B is inserted in the main circuit L. L. $n\ n$ is a branch circuit in which the Electro-Magnet T is inserted. The latter keeps the pendulum $Q\ Q$ in constant motion in the following manner: When a current passes through the coils of the Electro-Magnet; the armature Q of the Electro-Magnet is attracted; the pendulum therefore, will move towards the left, taking with it the spring R. which breaks contact with S; the circuit is thus broken and T is then without current. The pendulum Q falls back again, making contact between R and S, and causing a current again to pass through the Electro-Magnet. The motion of the pendulum is transmitted to the wheel m by means of $Q\ Q$ and a toothed wheel P fastened upon the axis of Q not shown in the figure. The shaft $D\ M$ of the wheel m carries the cone L'' which, when moving, touches the cone L' causing it to move also. The axis of L' has a movable weight $E1$ and is connected by means of a joint $E2$ with the shaft F of the registering apparatus. One end of the axis E. is connected with the cone c of the solenoid B, by means of the rod D. This motion of the iron core causes a lowering and raising of the axis E, at e which again causes the cone L' to touch the cone L'' with more or less surface, and in this way the ratio of the times of rotation of the two is altered as the attracting force of the solenoid B. alters. The registering apparatus, therefore, will go faster or slower in proportion to the strength of the current. The apparatus is similar in principle to the Dynamometer constructed by Charles A. Carus-Wilson but differs in the details. Similar apparatus has been constructed by Brush, Swan etc.

For what other great electrical invention is our age notable?

The Telephone. On February 14, 1876, Alexander Graham Bell, filed at Washington specifications for a patent in which the following language occurs, describing Bell's discovery: "The union upon and by means of an electric circuit of two or more

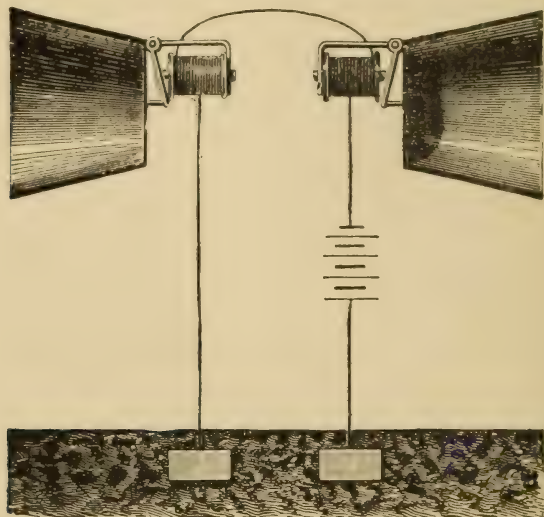


Fig. 27. BELL'S SECOND TELEPHONE.

instruments, so that if motion of any kind or form be produced in any way in the armature of any one of the said instruments, the amatures of all the other instruments upon the same circuit will be moved in like manner and form, and if such motion be produced in the former by sound, like sound will be produced by the motion of the latter." After seventeen years of litigation, involving a hundred million dollars worth of property, the above specification was held by the Supreme Court of the United States to cover all forms of talking through wires.

Who was Elisha Gray?

He invented a musical telephone and exhibited it prior to 1876, calling it a telephone. On the same February 14, 1876, —and it is claimed to have been just after the Patent Office

opened in the morning—this same Elisha Gray filed a caveat for a "Speaking Telephone," describing an "invention to transmit the tones of the human voice through a telegraphic circuit and reproduce them at the receiving end of the line, so that actual

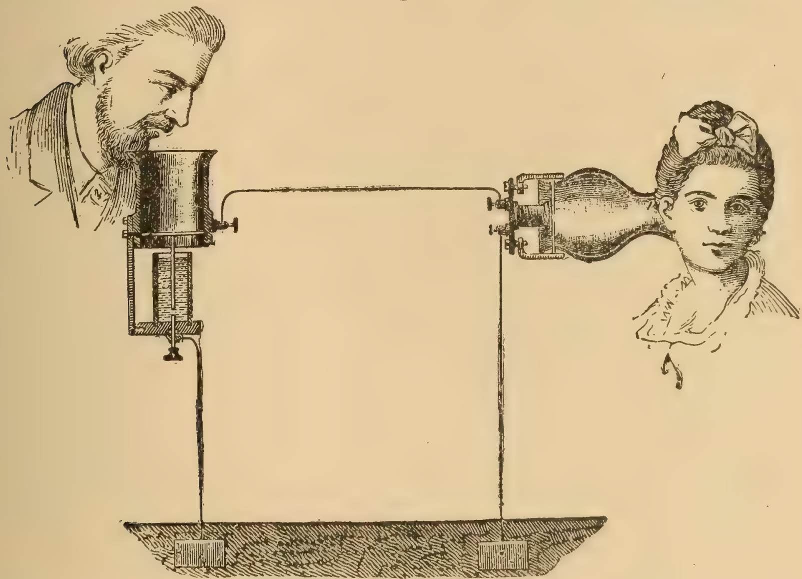


Fig. 28. GRAY'S TELEPHONE.

conversations can be carried on by persons at long distances apart." It was charged by Professor Gray, that a clerk showed his caveat and drawings to Bell's attorney at Washington, and that Bell thereafter amended his application, and secured the patent on March 7, 1876. Subsequent agreements between the inventors and their assigns, notably the agreement of November 1, 1879, gave to both Gray and Edison (the latter having made valuable additions to the transmitter) a small share of the immense receipts that followed the establishment of telephonic service in the United States.

What made the telephone so popular?

Its authenticity and usefulness. The sound of the voice is so faithfully reproduced that the sensation of personal intercourse

4

is secured. The connection is made quickly, and the cost and delay of messenger service, with all its inaccuracies, are avoided. Probably no other patent ever brought its owners a profit so large, with an expenditure of labor so small. In a city like Chicago, the subscriber for seventeen years paid an annual rental of $125.00 or $150.00 in quarterly installments. After 1893, some slight indulgences were offered to the public, but the essential powers of the monopoly remained unbroken, because of the great number of patented improvements that had been added to the apparatus, mainly at the Central Station, where the operation of connecting the wires of subscribers has been vastly simplified. The success of the telephone led to an increased popular interest in Electricity, and much good resulted in a general way.

You speak of a Central Station. Is there any power-house needed?

No. The central station is for the purpose of connecting the wires of subscribers together at their request. In large cities, this action is made easier and more rapid by the establishment of sub-stations, where wires that are in the same region may be united at the sub-station.

When I ring the telephone and call for a number, what happens at the central station?

As you ring, an electric light glows at the number of your telephone on a great board—the switch-board—which is full of small holes for pegs. A girl sits on a stool or stands before this board. Clasped to her ears are two small telephone receivers, made especially for her purposes. Before her there hangs on wires, a speaking disk or diaphragm, also made especially for her purposes. She sees a glow at the hole which has your number. She connects her disk with your number and asks you what number you want. You reply.

What does she do now?

She has in her hand an insulated wire, at each end of which is a peg, and this wire also runs through the wires that are at her ear, or may be so connected at her will. She places one of the

pegs in the hole at your number and the other peg in the hole at the number you want, and a bell sets to ringing at the telephone which you have called up. This bell she can ring again, if she finds that you do not get action. She knows all your troubles before you know them yourself, and unless she be a person of whom you should at once complain, it is always wise to speak to her in a low voice pleasantly. You call for two thousand and eight. She will "prove" the call by repeating it thus —two double aught, eight. You say, yes. In case you are convinced that she is careless and worthless, you have only to ask her to call the superintendent to your telephone, and he will correct or discharge her—or he will gather from the tone of your complaint and the character of your charge, that she may not be altogether to blame. It is to be noted that complaints of this nature grow less frequent with the improvement of communication on the telephone. Early in the new century automatic exchanges had been established in nearly a hundred small cities, with Ohio in the lead.

Describe the instrument at which I speak when I telephone.

In the first place you have in the mechanism of your own ear a telephone receiver and transmitter. The diaphragm or drumhead of your ear is practically imitated in the iron disks which

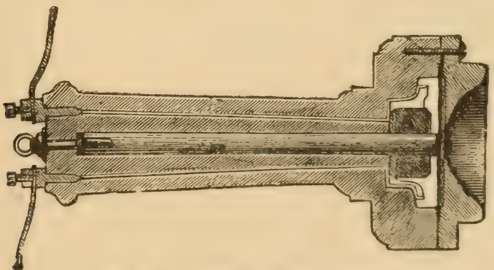


Fig. 29. BELL'S RECEIVER.

are placed one each in the receiver and the transmitter of the instrument. When sound strikes these diaphragms from without, the wire carries the sound-waves to the other end of the wire, where another diaphragm makes the same movements

that were caused by your voice at this end. In the receiver which you hold in your hand there is a Multipolar Magnet.

What is a Multipolar Magnet?

We know that a Magnet does not need to be crooked like a horseshoe—it may be a straight bar. This straight magnet in the receiver is made of four strips of separately magnetized steel, so that the diaphragm or disk, when you speak against it, plays against four poles at once—multipolar action—"many poles." But a small electro-magnet—that is, a magnet made by an electrified wire wrapped around it, is between the diaphragm and the long multipolar magnet, and the two wires that go out of the receiver attach to the little Electro-Magnet, and not to the large compound or multipolar Magnet. You could talk into this diaphragm, for it is a telephone, but it receives far better than it transmits. The electricians do not give a thoroughly satisfactory reason for the use of two different Magnets in the receiver, but the big compound one seems to act only as a governor or storage. The modern receivers are usually called "bi-polar" —two poles.

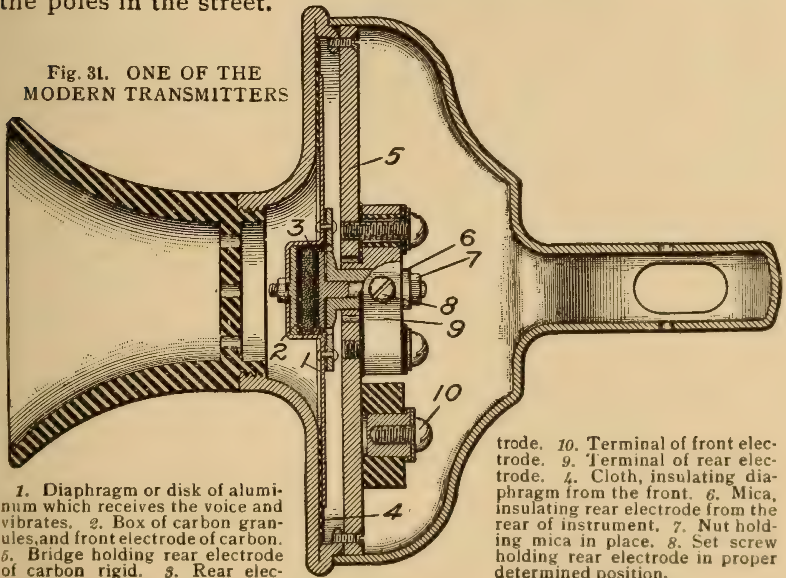
Fig 30. BELL'S TELEPHONE—MOUTH PIECE

Wherein is the transmitter different?

Its essential difference lies in the intervention of a box or chamber of carbon particles or granules between the front electrode that vibrates with the center of the disk you speak against, and the rear electrode that is touched and communicates the impulses of your voice into the wires. Edison invented a carbon button and Blake invented a platinum point. The box of carbon particles has displaced these devices. The inventors, since 1876, have brought into successful operation many types of the electrode fittings. In some the carbon chamber vibrates with the disk; in others, the carbon chamber is fixed to the rear or rigid electrode—to

what we might possibly call the non-vibrating electrode or pole. Both electrodes are of carbon. In the picture here on p. 69, the chamber of carbon particles vibrates backward and forward with the disk that you speak against. It is supposed by some that the granules of carbon play their own part in getting the niceties of the voice across and into the wire. The battery which electrifies the two instruments before you (transmitter and receiver) is in the box with the bells near by. The wire, in its circuit, begins and ends in this machine, and is called the primary or local circuit. Your voice causes sound or electric waves in this circuit, and your voice has no *direct* connection with the wire or the poles in the street.

Fig. 31. ONE OF THE MODERN TRANSMITTERS



1. Diaphragm or disk of aluminum which receives the voice and vibrates. *2.* Box of carbon granules, and front electrode of carbon. *5.* Bridge holding rear electrode of carbon rigid. *3.* Rear electrode. *10.* Terminal of front electrode. *9.* Terminal of rear electrode. *4.* Cloth, insulating diaphragm from the front. *6.* Mica, insulating rear electrode from the rear of instrument. *7.* Nut holding mica in place. *8.* Set screw holding rear electrode in proper determined position.

How is that connection secured?

By induction. When the street wire enters your box it coils into a fine silk-wrapped wire, which encircles the coils of your primary wire, and the Lines of Force from your local coil carry your voice over to the secondary coil, and it sounds much clearer than it would if it were the original current. You see that the arrangement at both ends is complex. There seems to the peo-

ple to be little use for the long Magnet in the hand-receiver, or for the primary coil in the box.

What was the General Progress of the Telephone?

Automatic and semi-automatic systems were invented and installed in hundreds of cities. By the automatic instrument—a truly wonderful device—the subscriber sets off the number of any other subscriber with whom he desires to speak, and calls him without the intervention of the telephone girl. No sooner was the aid of this famous personage eliminated than the wireless people began to telephone across short distances, eliminating also the wire, and though the advance of this almost mystic form of service was slow it was not the less sure, and surely astonishing. In the second decade of the century wireless telephony was regularly established in coal mines.

What is the History of the Telephone "Newspaper"?

The Telephone Hirmondo, an almost continuous daily report of markets, lectures, operas, and general news, was operated for many years at Buda-Pesth, Hungary. There was a corps of reporters to gather the news and a corps of stentors to speak it over the wires. At certain hours the subscriber could hear music, learned addresses, or light forms of auditory entertainment. The idea was copied in various cities of America. At Paris, in the second decade of the century, the Government instituted a telephone reporting system, whereby the proceedings of the law courts became audible to subscribers at points entirely outside the precincts of the bench and bar. This was done in the belief of the Government that justice would be advantaged by this extraordinary publication of hearings. The lawyer of Paris, in his rooms, can accurately time the progress of cases that are ahead of him.

Did the Long-Distance Telephone Fully Succeed?

Yes. It has become one of the chief factors of modern commerce and credit. The small cities adjoining large ones were attached to the city systems (with extra fee) as early as 1888. In 1890, after many failures, the Long-Distance Telephone between Chicago and New York was put in successful operation at a fee of nine dollars for five minutes'

conversation. Professor Bell was the first person to speak at the New York end, and Mayor Washburne replied from Chicago.

What other remarkable thing has been done lately with Electricity?

The Storage Battery has been perfected, and by its agency the electric launches at the World's Fair are supposed to have yielded a profit of $500,000. By attaching this battery to a Dynamo, certain chemical changes take place in the metals within. When the Dynamo is taken off, the chemical changes are reversed, and the work is more slowly undone. At Paris, the Societe Anonyme pour le Travail Electrique des Metaux, and at Philadelphia the Electric Storage Battery Company almost simultaneously discovered that a fusion of chloride of zinc and chloride of lead would, when put under electro-chemical action, produce pure lead in crystaline form, arousing much greater electrical action with less destruction of the original material than had ever before been attained. The result was the formation of an almost world-wide monopoly, and with recent further improvements these Chloride Accumulators, as they are called, are offered for rent in all houses, to run sewing machines, electric fans, heaters, cooking-stoves, lights, and for chemical purposes.

Is the Chloride Accumulator commercially successful elsewhere than in the electric launches? (See page 44).

Yes. The French Company runs three lines of street railway in Paris, two going to St. Denis, northwest of the city, and furnishes light to Paris streets in over 200,000 lamps of sixteen-candle power. The first installation of Storage Batteries at a power-house in America was at Merrill, Wisconsin, where, in January, 1895, a series of two hundred and forty Chloride Accumulators was attached to the Dynamo of the railway and lighting plants. When these Storage Batteries are full, the street cars can be operated without the Dynamo for hours at a time. Understand, that the Storage Batteries are not on the cars, but in the power-house. But suppose your Electric Light Dynamo stops at midnight. If you attached a Storage Battery to your light fixture or electrolier during the day-time, and

thus charged the Accumulator (Storage Battery), then, after midnight you could have electric light as long as the Accumulator stayed "alive." This is what would happen: While the current was acting in the acids of the battery, one form of lead was changing into another. When the intruding Electricity ceased, the *plus* plates unloaded into the *minus* plates, carrying back with them the matter that was deposited before, and

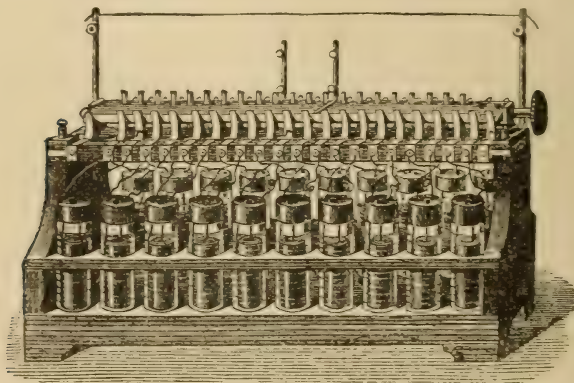


Fig. 33 PLANTE'S BATTERY (PARIS), AS HE PERFECTED IT BEFORE HE DIED.

setting up a current of electricity in the wires that led out of the Accumulator. The man who first tried to do this was Gaston Plante, and all who have reaped benefits from the Storage Battery, owe to him their thanks, for though he did not make it pay, his lead plates are today the real basis of the Chloride Accumulator. He lived and toiled in order that countless thousands might be the happier.

What advantages does the Electric Launch possess?

The batteries are placed around the boat under the seats, giving twice the room that can be found on a steam launch. There is little pleasure in running a steam launch, owing to the intensity of watchfulness which the owner or engineer must give to the many cocks, registers and gauges. Nearly every owner speaks of this strain. In hot weather, when these

WIRELESS TELEGRAPH STATION ON OCEAN STEAMER.

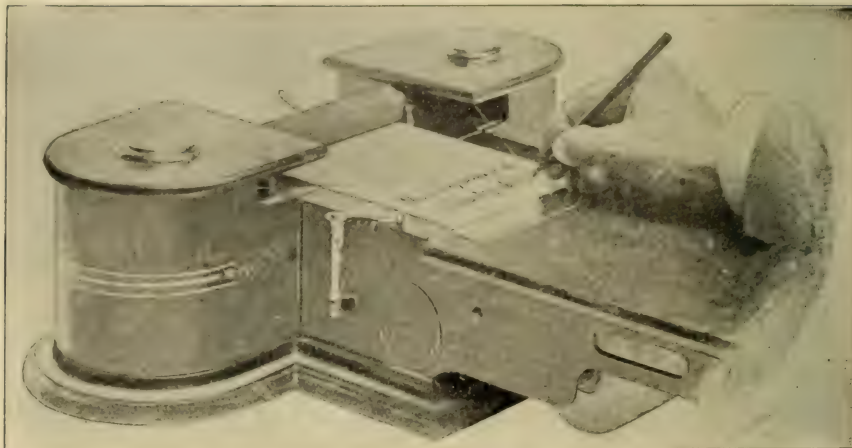


Fig. 34. THE TELAUTOGRAPH—TRANSMITTING INSTRUMENT.

Fig. 35. THE TELAUTOGRAPH—RECEIVING INSTRUMENT.

boats are most in use, the heat of the boiler, the fumes of the gas, or the smoke of the coal, are uncomfortable. It is to be said, however, that accidents from explosion are remarkably rare, if we consider the great number of amateur engineers that ply our little inland lakes. The electric launch does not dispense with the whirring sensation of the propeller-wheel.

What is the Early History of the Electric Launch?

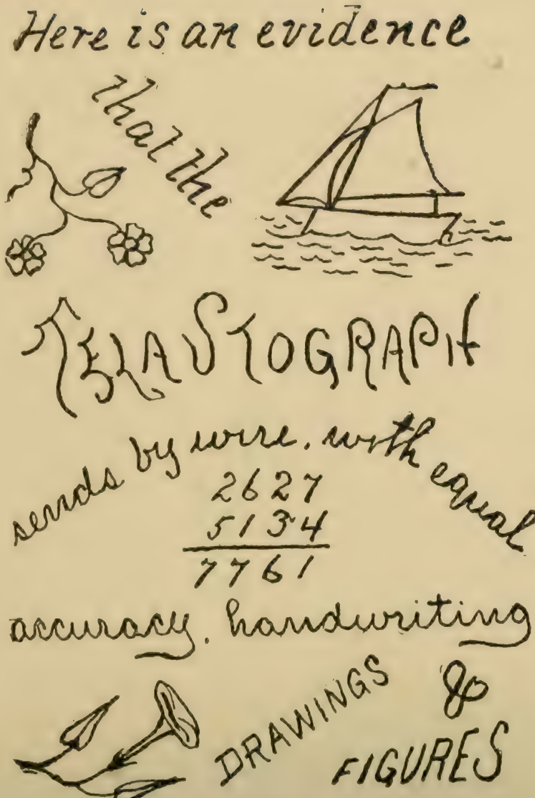
Trouve, at Paris, exhibited the first boat in 1881, at the Exposition. Reckenzaun put forty-five Accumulators on a launch at Vienna in 1882. Five years before the World's Fair at Chicago, electric launches were in regular use on the Thames River, at London, and on Lake Winandermere, in Lancashire. At the Edinburgh International Exhibition of 1890, the electric launches scored a decided success. At the Chicago World's Fair there were fifty thirty-six foot boats. There was a little electric motor on the propeller shaft. The Accumulators were charged at night at a station under the east platform of the Agricultural Building. Sixty-six Accumulator cells were used on each boat, and the cost for power was about fifty-five cents a day for each boat. General Barney, who managed the World's Fair fleet, set up a manufactory at Boston.

What Most Important Uses Were Made of the Accumulator?

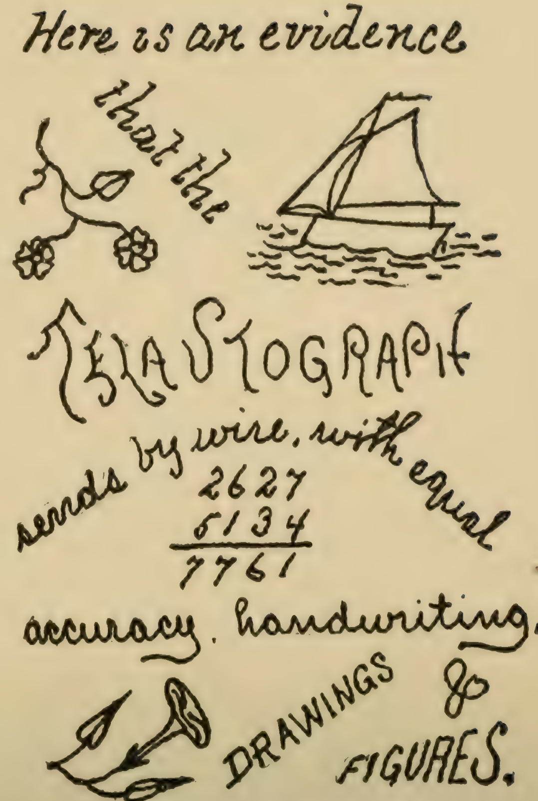
It was applied to automobiles for city or family use with unequivocal success. The electric automobile has become a symbol of elegance and luxury. After many costly undertakings, Accumulators of lasting qualities with economical advantages were applied to street cars and interurban transportation. In this way not only the noisome odor of gasoline is avoided, but the dangerous trolley-wire overhead or the "deadly third rail" is abolished.

What is the Telautograph?

A wonderful electrical instrument invented by Professor Elisha Gray, of Chicago, whereby hand-writing is transmitted by telegraph, and bank checks may be signed at a great distance. At the receiving instrument a pencil moves as if by an unseen hand, and at the other end of the wire from the sending



WRITING OF TRANSMITTER.



WRITING OF RECEIVER.

instrument. The pencil will write the word *lighten* and then go back and dot the *i* and cross the *t*.

Describe the Transmitter?

An ordinary lead pencil is used, near the point of which two silk cords are fastened at right angles to each other. These cords connect with the instrument, and following the motions of the pencil, regulate the current impulses which control the receiving pen at the distant station. The writing is done on ordinary paper,—five inches wide,—conveniently arranged on a roll attached to the machine. A lever at the left is so moved by the hand as to shift the paper forward mechanically at the Transmitter, and electrically at the Receiver.

Describe the Receiver.

The receiving pen is a capillary glass tube placed at the junction of two aluminium arms. This glass pen is supplied with ink which flows from a reservoir through a small rubber tube placed in one of these arms. The electrical impulses, coming over the wire, move the pen of the Receiver simultaneously with the movements of the pencil in the hand of the sender. As the pen passes over the paper, an ink tracing is left, which is always a fac-simile of the sender's motions, whether in the formation of letters, words, figures, signs or sketches.

What is Electrocution?

Execution of death sentence by Electricity. Through the efforts of Elbridge Gerry and others, the State of New York determined to kill its condemned murderers quicker and with less pain than through the ordinary means of hanging. In May, 1889, William Kemmler of Buffalo, murdered his wife, and was the first person to come under the operation of the new law. The Westinghouse Electric Company made a strong legal contest in behalf of Kemmler, but the Supreme Court of the United States decided in favor of the State of New York. Kemmler was accordingly killed by Electricity at Auburn Prison, August 6, 1891. The arrangements were crude, as the Dynamo which made the current was at a distance, and the executioner had no

volt meter or register by which to measure the current which he was using. The murderer was seated in a rough chair. He was then made a part of the circuit coming from the Dynamo. This was done by fixing a cap on his head, and other caps on his limbs. The caps or electrodes became loose and the body was burned, but after two attempts, Kemmler was pronounced dead. The chair was condemned as inefficient, and was afterwards exhibited in the Anthropological Building of the World's Fair of 1893. Jugiro, a Japanese murderer, of New York City, was the second culprit upon whom sentence of death was executed in this manner, and the custom is now accepted as humane and successful.

What is the Electric Fan?

A useful small brass wheel, shaped like a ship's propeller. In an iron sphere at its rear is an Electric Motor—that is, a Dynamo reversed. Wires connect the Motor with a power-house. Turn a switch, and the wheel revolves with high speed, sending out a column of moving air, which may be felt for a distance of twenty feet in a room that would otherwise be without an appreciable draught.

What is an Electric Ventilator?

Practically the same apparatus on a larger scale. The wheel is made of iron, and placed in a circular aperture, usually leading directly to the open air. Here the air from the room is sucked into the blades of the revolving propeller, and a corresponding quantity of fresh air is attracted into the room through the doors and windows. The Electric Motor stands on a shelf near by, and a belt carries its power to the fan in the wheel window. Many crowded lodge-rooms, theatres, restaurants and department stores within the circuit of power-houses are thus supplied with ventilating facilities. It is of the greatest benefit in flouring mills.

What about Electricity and war?

The Search-Light, mounted on a wagon, with its own steam engine and Dynamo, searches the battle-field for the wounded, and carefully explores the most distant points of the country for the enemy. The modern war vessel is wired from stem to

stern and carries an Electrical Engineer. The Trenton, in 1886, was the first ship to be served with incandescent lights. The Search Light is on the conning tower. The officer in the conning tower fires the guns himself, whether singly or as broadsides. Let us see how that is done, as the same device may be used for firing any explosive blast. An open tube filled with powder is connected with the powder of the cannon. Into this tube and its powder runs a platinum wire wrapped with gun cotton. To this wire the wires of an ordinary battery are attached. The officer on the conning tower connects the two wires by pressing his button, and the platinum wire becomes so hot that it sets fire to the gun cotton. Gun cotton is made by soaking cotton or other fibre in nitric and sulphuric acids.

What is an Electric Torpedo Boat?

A charge of explosives is carried in a cigar-shaped sub-marine vessel. There is an Electric Motor on board, served with an Electric cable from shore. On a reel is wound the cable that may be paid out as the torpedo moves away. At the other side of the reel lie coils of cable that may wind up to take the place of the cable paid out. The Dynamo on shore starts and the Motor on board goes, therefore its propeller goes. Steering apparatus is operated in the same way—all from shore, or from the conning tower of the man-of-war. This is the general idea of the Sims-Edison Torpedo Boat. It is designed to carry a mine of explosives under or near a hostile man-of-war, and to blow the enemy to pieces or cause great damage. In February, 1898, the first-class battle-ship Maine was blown to pieces in Havana harbor.

What is the Gymnote?

It is a successful Electrical Submarine Vessel made for the French Navy by Zede, Krebbs and Ramazotti. The name is taken from the Latin name of the animal known as the electric eel. This vessel, built since 1888, is fifty-nine feet long, six feet in greatest diameter, and cigar-shaped. She carries three men on board. She is designed to travel at the surface of the water usually, and at ten knots an hour. She can be sunk to eight

yards beneath the surface and then proceeds at half the speed. The armature of the Motor is built up on the shaft of the four-bladed screw propeller wheel, which protrudes at the rear of the boat. Movable horizontal outside planes or guides, together with the force of the screw, direct the level at which the boat shall proceed; if these planes are slanted with the ends nearest the center of the boat turned downward, the screw will force the boat downward. At the center and top of the boat there is a cab-window for the engineer. The Storage Accumulators, weighing six tons, serve as ballast, and give out fifty-five horse-power. Water-tanks are filled as the vessel sinks, and emptied as she rises, to assist her movements. Chambers also contain compressed air, and whenever the air pressure inside is too great, foul air will escape. Incandescent lights are used on board. The French Government built a larger boat on these lines at a cost of $225,000. George C. Baker, of Chicago, tested a very ingenious and interesting submarine electric vessel in Lake Michigan in 1892. She carried an active steam engine when afloat, charged her Accumulators with a Dynamo, and after she sank, the Accumulators used the Dynamo for a Motor. All the great naval powers of the world have now provided themselves with submarine vessels of war.

What is the Electric Log?

It is a Marine Cyclometer, and measures the speed and progress of the ship. On the end of an electric cable, hung out from the ship, is a screw wheel. At every revolution of the wheel, the electric circuit inside the cable is broken and closed. A dial on board the ship records these movements, much as the cyclometer on a bicycle records the revolutions of the bicycle-wheel.

What is Nikola Tesla's Oscillator?

It is a combination of steam engine and Dynamo, which is expected to save 18 per cent. of friction now existing in the average steam engine, 10 per cent. of belt friction as engine and Dynamo are usually connected, and 32 per cent. of wasted energy occurring in such a Dynamo as we have already described —that is, the form of Dynamo in general use. Let us imagine

a steam-chest; when the steam goes in, out goes the piston. On the piston is an Armature, the armature of a Dynamo. When the piston goes out it enters the Magnetic Field of an Electro-Magnet or coil, and a current is set up in the piston. When it goes back, another piston takes its place. Tesla's Oscillator was furnishing the power for sixty incandescent lights when his laboratory burned in 1895. The pistons are vibrated eighty to two hundred times a second, or more rapidly than the eye can follow them. The first Oscillator was built on a vertical plan, as shown in our illustration. The succeeding examples have been made on a horizontal plan. The machine shows that it makes no difference in what manner a wire enters a Magnetic Field, whether by rotation or piston movement. The Tesla machine caused a sensation among practical electricians, but in the meantime, attention was attracted to Edison, who hoped to turn heat into electricity without the intermediation of steam.

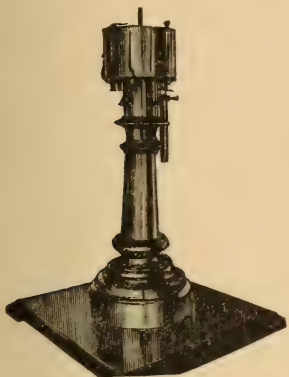


Fig. 36. TESLA'S OSCILLATOR.

Yes. Tell me about Thermo-Electricity.

Thermo-Electricity means Electricity that is generated by means of heat. The Clamond Generator, a laboratory machine, is a pile of rings made of metal alloys. Between the rings of metal are rings of asbestos. By burning a light in the centre and allowing ordinary radiation from the outside, a feeble current of Electricity is generated. Edison and others expended years of study and experiment in trying to develop this idea, and great improvements have been made in the Clamond Generator. Dr. W. Borchers, of Duisburg, Germany, has attacked the problem on what we may call its chemical side, hoping to act on coal with acids, and by cold combustion to secure the quantity of Electricity that is stored in every piece of fuel. The mechanism of animal life offers examples of cold combustion, and in the warmest blooded creatures the heat rises only to less

than 99 degrees above the Fahrenheit zero. Dr. Borchers has announced to the German Electro-Chemical Society that the cold combustion of the gaseous products of coal and oil in a gas battery, and its direct conversion into electrical energy can certainly be accomplished. Edison is understood to be part owner of a coal mine, and has a large personal interest in the success of these experiments. It is calculated that of 100 per cent. of energy stored in the fuel which is used under the boilers at the power house, only 15 per cent. goes into the "live" wire that hangs in the street—a waste of 85 per cent.

What is the Electric Weed-Killer.

This device is attached to a locomotive where the weeds or thistles are flourishing on a right-of-way, and strong currents sent into the vegetation as the locomotive passes destroy the growth.

What is the Brott System for an Electrical Railway?

Its experimental line is built between Washington, D. C., and Chesapeake Bay. It is commonly called the Bicycle Railway. The General Electric Company guarantees generators, motors, and accompanying electrical apparatus that will propel these cars at the rate of 150 miles an hour—that is, the axles will go around fast enough if the atmosphere shall allow the passage of a car at such a speed. Inasmuch as the hundred-ton steam engine "999," shown at the World's Fair of 1893, attained a speed of 100 miles an hour, the claims of the Brott System are admitted by scientists.

Why is it called a Bicycle Railway?

Because the weight of the car is to be sustained largely on one central rail, two other upper and side rails serving only as guides, and rarely in that way. That is, there will be three rails, a central one low down and two outer ones about six feet up in the air. When the car is going rapidly, its side-wheels, which protrude like the trunnions of a cannon, will not touch the side tracks, as the car will sustain itself vertically like a bicycle

in motion. The electric motor will have its armature on the car axle, so that the axle will go as fast as the armature revolves within its Magnetic Field.

Why should this car go so fast as is expected?

Because the rotary motion of an old-time locomotive wheel is the result of the motion of a steam piston that stops still twice for every revolution of the wheel, and no such wheel can approach the possible speed of the rotary action of an electric motor. Again, ball bearings and bicycle construction give to the light car used a saving in friction as great as the difference in friction between the action of a bicycle and a farm wagon. The old system carries a ton of weight with each passenger; the new carries 400 pounds. The route to New York from Chicago is to be covered in eight hours. These light roads will come into favor first at pleasure resorts, and one is building at Minneapolis. The electric current can be delivered at all speeds. The power-house will operate for fifty miles. Lubrication and air pressure offer no unknown difficulties, and a very fast railroad of this order is assured. The line is practically elevated, and all stretches of road between stations must be perfectly straight. It is thus to be seen that it will not work in the mountains, and must take the long way across the continent.

What is the Kinetoscope?

In its full form it is the Kineto-Phonograph, an instrument for conveying to the eye and ear, at the same time, a record of the acts and sounds of persons and animals. As the public has seen it for several years, it is simply the Kinetoscope, little effort having been made to conjoin the Phonograph. As the Kinetoscope is shown it is not electric, save that is run by a Motor. The Kinetoscope has its origin in the Tachyscope, the Zoetrope, and other toys and machines that have been long familiar. Either the observer looks through a lens on a passing tape of lighted photographs, or this tape is thrown on a screen, and called Vitascope, Eidoscope, etc. But if we enter Edison's workshop and see how the photographs and phono-

graphs were prepared, we shall not cease to admire the patience, genius and success of this great American, the type of Modern Man.

Describe Edison's Kineto-Phonographic Theatre?

It is a simple small room, growing less toward the stage end, where there is a black background. Twenty arc lights, with reflectors, throw fifty-thousand candle-power of illumination on the actors. At the proper distance stands the phonograph, with

Fig. 37. TAKING PHOTOGRAPHS AND WORDS FOR KINETOSCOPE PHONOGRAPH.

its big horn outstretched to catch every sound. This Phonograph is electrically connected with the Kinetograph (not Kinetoscope, this time), alongside. Now the actors begin, or the pugilists commence to box. Professor Edison succeeded in taking forty-six photographs each second. Inside a drum, a highly-sensitized tape of celluloid, perforated at the edges, runs

at the rate of twenty miles an hour. But the tape stops still forty-six times a second, and is at a stand nine-tenths of the time. As it stops, a shutter opens and the photograph is taken. The holes in the tape enable the locking machinery to start and stop the tape properly. When the tape stops, the electrical connection with the Phonograph regulates that instrument accordingly. We will now suppose that Corbett and Courtney spar for four rounds—a scene that first demonstrated the success of Edison's labors. Each round lasts exactly a minute. As the athletes strike and leap, clinch and break away, the tape makes two thousand seven hundred and sixty stops, and that many pictures are taken on a very long strip of celluloid. The electric part of the operation is now over. To merely *see* the reproduction of this boxing match, the tape is reeled on spools, a lens or two may be put in a case overhead, an incandescent light may be lit under the lens, beneath the transparent tape, and the Motor set going. The tape goes by in one minute. The motions of the athletes are faster than they would be in a natural bout, and the eye detects a jerky movement, but to all intents, the picture is a complete and moving one, though moving too rapidly.

What will be the uses of the Kincto-Phonograph in the future?

It will carry a much improved record to the next ages. Costumes, battles, volcanic eruptions, conflagrations, cyclones, voices, gestures, and physiognomy, the occult impressions conveyed by great men, orators, leaders, teachers, reformers, inventors—all these records will be bestowed by the Nineteenth Century on the coming cycles of time; and education, thus aided by the past, will proceed more rapidly to the enfranchisement of the race.

Tell me about the "Chaining of Niagara Falls," as it is called.

The mathematicians give to the fall of water at Niagara an energy of 8,250,000 horse power. The first or present power-house of the Cataract Construction Company utilizes 100,000 horse-power, and the canal and tunnel already made will run

two such power-houses. The energy utilized at the World's Fair of 1893, by the greatest battery of steam boilers the world had ever seen, was reckoned at less than 30,000 horse-power. Niagara would still serve *164* other similar power-houses.

What did the Company do?

It began its labors in 1889 and got practical results in 1895. It dug and walled a big canal to the site of the power-house.

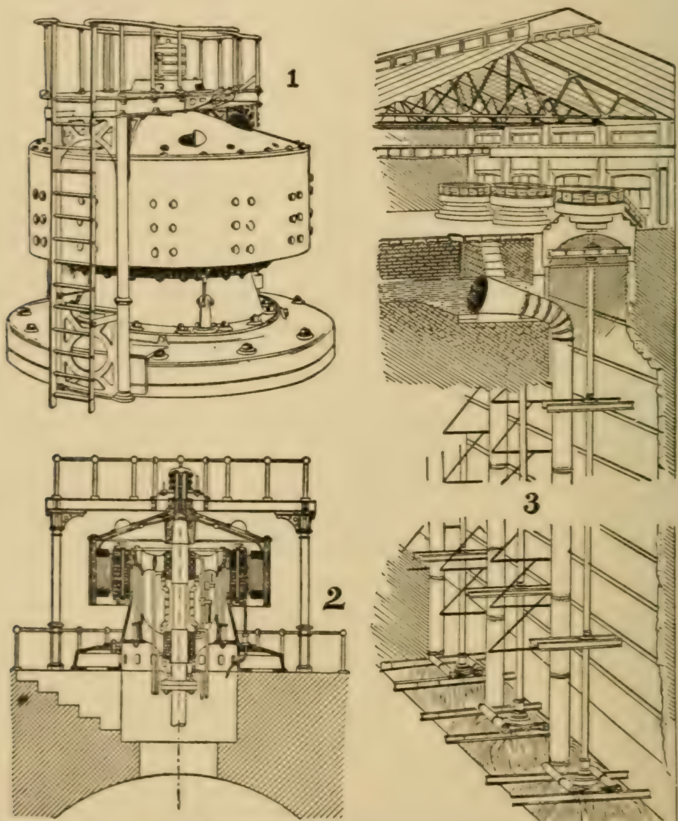


Fig. 38. 1. THE FIVE THOUSAND HORSE-POWER DYNAMO AT NIAGARA. 2. CROSS SECTION OF SAME. 3. INTERIOR OF POWER-HOUSE AND WHEEL-PIT.

Then it sank a well or long wheel-pit alongside of the canal, where it could get water conveniently. Note that this deep well, at the earth's surface, was one hundred and forty feet long and twenty-one feet wide. This big well was sunk in the solid rock to a depth of one hundred and seventy-nine feet. Now let us view the general situation. The Niagara River, running from Lake Erie to Lake Ontario, falls over a ledge of rock a distance of from one hundred and fifty to one hundred and sixty-four feet. At the bottom, the gorge into which the river has fallen also runs rapidly down-hill. The Company has extended its canal until it has been able to secure a private water-fall of one hundred and seventy-nine feet, although the actual fall of the water that is used is one hundred and thirty-six feet. After it is used, it follows a tunnel more than a mile and a quarter and empties into the gorge below the Falls. Thus, it goes a quarter mile in the canal; it falls one hundred and seventy-nine feet in the wheel-pit; it flows a mile and a quarter in the tunnel and again joins Niagara River, but man has caught, meanwhile, 50,000 horse-power of its energy, and needs to do that much less labor with his hands and back in order to live upon the earth.

How does the water enter the wheel-pit?

In pipes or penstocks. At the bottom of the pit and at the end of the penstock is a turbine wheel. When the water comes to the wheel, the wheel goes around. The steel shaft that ascends from the turbine wheel reaches the surface in the power-house, and, of course, turns around with all the power of the wheel. The shaft is a rolled steel tube of thirty-seven inches in diameter. At its various bearings, on the way down to the bottom it becomes solid steel, with a diameter of eleven inches. Now, this shaft weighs thirty-six tons, and forty tons must be hung on it, as we shall show, and then the downward pressure of the water in the penstock is also to be resisted. Was it not probable that something would break?

How did they solve those questions?

A commission of engineers met at London to decide on general plans. Its members were, Lord Kelvin, of England, Chair-

man ; Professor Cawthorne Unwin, of London, Secretary ; Professor E. Mascart, of Paris, and Dr. Coleman Sellers, of Philadelphia. It was agreed that the power should be turned into Electricity instead of compressed air, because it was believed, the developments in Electricity bade fair to be more valuable than any improvements we might reasonably expect in the use of compressed air. No other methods of utilizing energy were seriously considered. It was determined that the water should leave the penstock in an upward direction, lifting the turbine wheel rather than dashing down on it. That is, the water, coming out of the penstock, moves with a lifting motion against the disk that carries the movable blades of the upper turbine. You must understand that nowadays, when a water-wheel's blade comes around where it opposes the water, it collapses and offers no resistance. The turbine wheel is five feet and a half in diameter, and goes around two hundred and fifty times a minute. Now also understand, that a shaft of steel rises out of the center of the turbine wheel—that is, on the wheel, to the top of the wheel-pit.

Well, you spoke of forty tons that were to be loaded on this shaft. What was that?

The Dynamo. The top of the shaft was to be a Dynamo. It must be different from any Dynamo ever made before. It must not weigh more than forty tons, and it must have a fly-wheel effect of 550,000 tons. The fly-wheel in gearing, is a storage battery of power. It condenses or stores power, and equalizes the force of the machine. It is what the Accumulator is to Electricity. Now, naturally, the armature would be built up on the top end of the long steel shaft, but this would offer no fly-wheel. If the fly-wheel were added, there would be too much weight. So Nikola Tesla and the engineers solved the problem by fixing the Magnetic Field—that is, the Electro-Magnets and their Lines of Force—to the shaft itself, and the Magnetic Field revolves around the armature, which is stationary. It is as though the shaft run by the steam engine in the Dynamo at your nearest street car power-house stood still, and the iron jaws of the Electro-Magnets that

now inclose it, were turning somersaults around it. Now the shaft revolves, and the armature sends into its wires 5,000 horse-power of energy, or about twice the power of the largest Allis steam engine at the World's Fair, 1893. Thus, for each 50,000 horse-power of this power-house, there must be ten turbines, ten penstocks, and ten of these back-action Dynamos. The wires of the Company will carry working currents to Motors 100 miles away

What has been done so far?

Niagara was only the forerunner of vast electric installations all over the world, such as the thirty turbines at Keokuk, Iowa. But, at Niagara, the electric furnace was first put to work commercially for the immeasurable betterment of mankind. At the factories of Dr. Acheson the hardest cutters and the very softest lubricants were manufactured after many years of patient chemical research by this great discoverer. At other factories Calcium and Aluminum carbides and "artificial Nitrates" are manufactured. Phosphorus is isolated for the match companies. The fall in the price of Calcium was remarkable. Electric currents of voltage as high as 70,000 are safely and practicably carried for distances comparatively long. On one occasion, at an electrical fair in New York City when Edison sent a telegraphic dispatch around the world, machines were driven by power that came from the turbines in the Niagara wheel-pit.

Is Electrotyping an Electric process?

Yes. Distinctively so. The plates of this book are thus cast from the types of softer and less durable metal than copper. By making electro-plates many economies are wisely practised. First, the types are set into the form desired and dusted with plumbago. Then the form is turned face downward in a flat vessel of beeswax, and properly pressed. Then the wax mould thus secured is suspended in a bath or battery containing usually a mixture of sulphate of copper and water, and a plate of copper is also put in the water. A Dynamo is turned on to secure rapid deposits of copper on the wax, and after a night in the bath, the wax comes out coated with copper, making a thin

copper shell. The shell is warmed so that a sheet of tin foil will adhere to its inside or back, and upon that tin foil melted type metal is poured, to give the plate strength. The plate can then be fixed upon a wooden block, or the backing can be made as thick as a type-form; but for book-work the plates are made so that they may be used on blocks which the pressman furnishes. When not in use, a set of book-plates is kept in strong boxes. The great objection to electrotyping is that it is too slow for modern times. The *papier mache* process of stereotyping, or making type-metal plates, is an entirely different process, without the use of electricity, except as power.

What is the Gas Flash-lighter?

It is an electrical arrangement and device, whereby illuminating gas can be lit by touching a button in the wall. A battery is kept in the basement, which is inspected and attended by the company. The gasolier is wired. Around each gas-burner is a jacket containing a tiny motor and stopcock. The motor is set going and opens the gas valve. An arm holding a wire-pole swings across the field of escaping gas; the spark flies from pole to pole at the nearest point to the other pole, and the gas takes fire. By this means, the light can be turned on or off by touching buttons, as if it were an electrolier instead of a gasolier.

What is Electro-plating?

The same as Electrolysis and Electrotyping, only that one

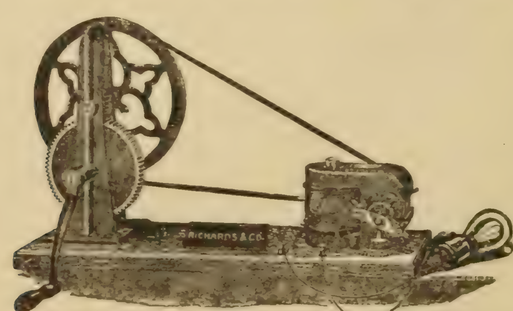


Fig. 39. DYNAMO—HAND-POWER, FOR ELECTRO-PLATING, ETC.

metal is deposited on another, a superior on an inferior quality,

for many commercial purposes, but principally by jewelers and gold and silver smiths. In 1897, the price of silver had fallen so low, and competition had become so keen, that plated silver goods were to be had for the old price of tin. Jacobi, in Germany, John Wright, in England, and De Ruolz, in France, were the first great silver-platers. The vat holds a solution of cyanide of silver in cyanide of potassium. The objects to be covered with silver are made of copper, zinc and nickel (german silver). These are washed in hot caustic potash, and before the washing are "scratch-brushed" with wires in a lathe, the wires being moistened with stale beer. Baths or "pickles" of nitric and other acids are also used. The articles are then "quicked" by dipping them in a solution of nitrate of mercury or cyanide of mercury. A thin film of quicksilver is deposited on the article, which is now rinsed with water.

What comes next?

It is ready for the electric bath. The vats were once made of wood, but later, wrought iron was substituted. Plates of silver are suspended from a frame which connects with the positive pole, or anode. The articles to be plated are suspended from a similar frame that connects with the negative pole, or cathode. (See the chapter on the X Ray). An ounce of silver will heavily plate a square foot of surface. The best manufacturers advertise triple-plated goods, implying that the article went in the silver bath three times. On removal, the plated objects are dipped in hot water, again "scratched brushed" with beer and dried in hot sawdust.

What is Electro-Metallurgy?

Any similar process, by which one metal is deposited on another. Thus, copper plates for bank-notes are hardened by the deposit of iron. Flowers and insects are preserved by the deposit of beautifying metals. Exposed iron work is coated with copper. Plaster statues are coated with metal. Gold jewelry of delicate workmanship is deposited by electricity in molds of gutta percha or plaster. Watch cases have offered a popular form of gold plating.

What has been the effect of Electrical progress on the metallic industries?

A revolution has followed in these lines. Copper, (except from Lake Superior) Zinc, Manganese, Chromium, Aluminium, Sodium, Potassium, and all the Chlorates are produced by Electrolysis. Carborundum, to take the place of emery dust, is made by a current of Electricity. Calcium Carbide for acetylene gas, is made by Electricity.

What happened to burglar-proof safes?

It was discovered, in 1897, that an electrical expert could fasten his apparatus to an electric light fixture, and with a carbon candle, bore a hole in any safe whatever inside of two minutes. The hole could be made as big as a man's arm. The hardest steel melted like ice before the electric light thus applied. The proper defense is by electric warnings.

How are maps commonly made?

A copper plate is first covered with lamp black, and then with wax. Names of places, etc., are separately set in type in small hand-holders and stamped into the wax down to the black. The lines are also drawn down to the black. Thus a mold is made. This mold is then suspended in an electrotyper's bath, and copper is electrically deposited on the wax mold, making the electrotype or "cut" of the map. More maps are made at Chicago than anywhere else in America. Maps may, of course, be engraved on copper, steel or stone, without the electrical method.

Finally, tell me a wonderful thing that Electricity is yet to do?

We are to see through a thousand miles of wire. This instrument is the Telectroscope—*to see afar*. It has been hypothetically invented by Leon Le Pontois, a French savant, and it is declared to be as clearly conceived as the theory of Columbus that a vessel could sail to the west around a spherical Earth. Before making an attempt to outline this invention. let us mark

the ancient experiment of Professor Pepper, a noted lecturer, who burned a Drummond light in a dark camera. In this camera was a revolving disk that let out a slit (or thin sector) of a circle of light each time the disk revolved. This revolution was enormously rapid. But still a flash of light would be projected each time the slit came around. In front of the camera was a very large wooden wheel. Now if the wooden wheel stood still in the dark—for the lecture-room was also darkened for this experiment—then we would see just one spoke, the spoke on which the little slit flashed its light. A boy now turned the big wooden wheel, while Professor Pepper turned the metal disk. The wheel would be going so fast that its spokes could not be discerned if the lights of the hall were on. Thereupon the following phenomenon was shown: The slit was lighting each time a separate spoke of the big wheel, and yet the speed of light is so great and the registering power of the eye so good, that although the big wheel was revolving three hundred times a minute, still it apparently was not moving at all—in fact, it would oscillate slowly back and forth—a wonderful illusion, teaching that the eye cannot always be sure of what it sees.

What has this to do with the Telectroscope?

The new instrument retains the revolving disks, and oxygen and hydrogen gases for the Drummond light, that made the Pepper experiment. We will now suppose a picture—let it be a shining one, such as a set piece of fireworks—and we want it to be seen a thousand miles away. The firework would cast its image toward a revolving disk with twenty holes in its outer part. The light coming through these disk-holes would strike an oxy-hydrogen light that would pulsate with the extra impressions of the disk-rays. All these pulsations are going over a telephone that is fitted to receive them, with a proper transmitter to exaggerate the impressions. At the other end of the telephone wire a similar disk is rotating by means of the same electric propulsion—that is, when a certain hole, say *a*, in disk No. 1, goes past the top place in the disk's orbit, then hole *a* in disk No. 2, a thousand miles away, is at the same place in its circular path. Now the regular light vibrations are coming

through the wire; on top of these vibrations are the extra vibrations received on the Drummond light from the light coming through the disk, and each of these light rays, being of all kinds of powers, has chosen a different route over the wire. The picture is now passing over the wire. The Drummond light is burning from gases that are regulated by the diaphragm of the telephone receiver—that is, *the light is exactly duplicated* a thousand miles away. Disk No. 2 revolves so as to catch the whole of the light. This varying light is caught by lens and reflector and thrown with all its vividness on a ground glass. Through the other side of the ground glass the human eye is able to see, in the center of the vivid background, the original picture of fireworks, that shone on the disk at No. 1. The picture has not passed, you say. Neither has your voice at the telephone passed. Certain pulsations caused by the voice have not been permitted to dissipate into nature so rapidly as they usually do. When man shall triumph over the electric difficulties of making two disks turn together, and two Drummond or electric lights burn together synchronously—that is at the same time—*we shall see afar.* We shall see fireworks, total eclipses that take place in Norway, operas, ballets, transformation scenes, great men, and distant relatives. Thousands of practical uses may evolve, undreamed of as yet.

The X Ray.

What is the X Ray?

It is supposed, by Tesla, to be an unseen flow of matter, driven with high speed, through the interstices of other matter that is never very dense. It is supposed by others to be the movement of light rays in waves that are forward and back—that is, the waves move like a serpent's tongue.

When was the X Ray discovered?

On the 8th day of November, 1895, at the Physical Institute of the University of Wurzburg, a town of 45,000 inhabitants, in Bavaria, Germany, Dr. Wilhelm Konrad Roentgen (pronounced Renken) was studying the effects of an electric discharge through a glass tube from which the air had been withdrawn. He was in a dark room, and had covered the tube with a shield of black cardboard, through which not even the rays of the electric arc light would pass. At a point some few feet distant, there lay a piece of barium platino-cyanide paper (sensitive paper). As the light of the electric discharge played in the covered tube he happened to notice a black line or shadow moving on the sensitive paper. If the light came from outdoors it must be shut out; if the room were really dark, where did the light escape from the tube? Investigation proved that no light was coming either from the outside or from the tube through the cardboard. In a short time, Dr. Roentgen had learned that rays were flowing through the black cardboard—rays that would go through a book or a wall as well.

When did the world hear of it?

At the December, 1895, meeting of the Wurzburg Physio Medical Society, Dr. Roentgen made a full report. The news came to London by telegraph from Vienna, that the Wurzburg

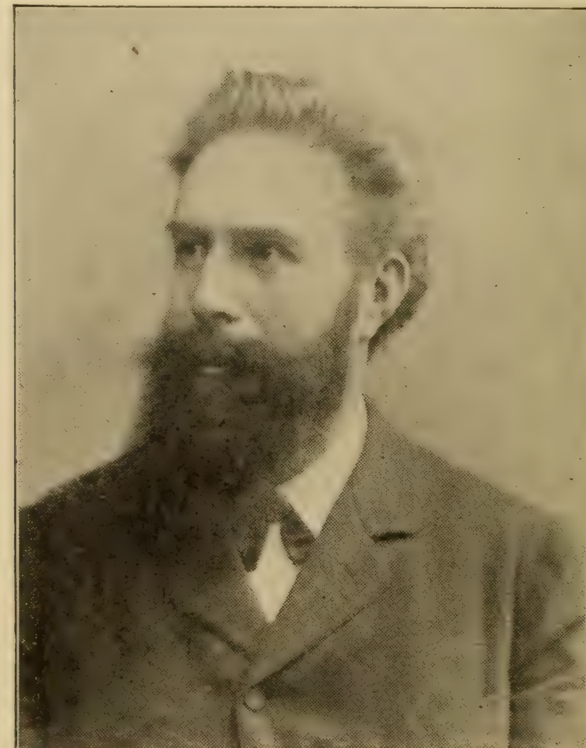


Fig. 41. DR. WILHELM KONRAD ROENTGEN.

Professor had found a new kind of light. This was followed by mail advices, giving the discoverer's clear and remarkable report, and it is not unlikely that within four weeks the people of every civilized country in the world were experimenting with the X Ray, taking photographs of the bones of the human hand, and discovering the metallic contents of a pocket-book without opening it.

Tell me something of the earlier history of the X Ray.

The X Ray was not possible without long-continued study of the subject of Fluorescence or Phosphorescence, Radiance and Induction, as we will here try to show you. In 1852, Professor Stokes inserted a bull's eye of blue (cobalt) glass in the wall of a dark room. Through this bull's eye a ray from the sun was admitted, making a feeble violet colored light. In front of the bull's eye he held a piece of canary glass (glass colored yelowish green with oxide of uranium). This canary glass lit up brilliantly in the feeble light. Now he held, further away, but still in the track of the light, a piece of glass colored a brownish yellow with the oxide of gold, and this glass became transparent. But if the Professor placed the gold glass before the uranium glass, the gold glass would not be transparent. In other words, the violet light of the bull's eye would not go through the gold glass until it had first passed through the uranium glass and certain preparation had been given to its rays. We all have seen the rainbow effects of a three-cornered piece of glass lit by the sun—the spectrum. It had long been known that light fell outside of the blue band of the rainbow. This unseen light would effect chemical changes. Therefore it was light, or at least energy, and it was called the ultraviolet (that is, beyond the violet) ray. It was, of course, thought that Roentgen had found a new property of the ultraviolet ray. Stokes, however, with his fluorescent glasses—or glasses that would store up light—made the ultra-violet rays visible under many different circumstances. All luminous paints are made of materials that store light rapidly and emit it very slowly. The variations of color in the same chemicals at different times and the color effects generally, were never explained.

State again the general facts of the rainbow and Fluorescence.

The violet rays of the rainbow are the ones that cause the most chemical action—therefore these rays are called *actinic*. The yellow rays give the most light. The red rays give the most heat. Beyond the violet band of the rainbow are the ultra-violet rays, ordinarily not visible. They vibrate faster and

their waves are shorter, than the violet rays. But these ultra-violet rays, when passed through certain substances, become visible in a luminous state of that substance, and this luminosity is called Fluorescence. Now inasmuch as light is often desired without heat, the electricians have long sought to increase the vibrations of their machines in order to get a white light.

Tell me about intensity coils—Ruhmkorff's, Tesla's, etc. Who was Ruhmkorff?

Heinrich D. Ruhmkorff invented the Ruhmkorff Intensity Coil in 1851. He died at Paris, December 21, 1877. He found that the most rapid movements could only be secured by wrapping one coil of wire over another. The currents were generated in the inner coil by Induction. The core of the coil was itself made of wires. A Dynamo sent its currents around the outer coil; the inner coil set up its own currents by Induction, and fed them into a condenser or Leyden jar; the Leyden jar discharged with increased velocity. Thus the Dynamo sent a current this way and that way around the small coil ten thousand times a second. This rapidity was multiplied beyond measure by the Leyden jar—up into the billions in a second. A feeble Leyden jar whose waves play only a few hundred times a second makes waves that are each twelve hundred miles long; the shortest wave Tesla produced was thought to be seventy feet long. The wave needed to make white light is thought to be one fifty thousandth of an inch long. Thus electric waves are still far in the rear of light waves.

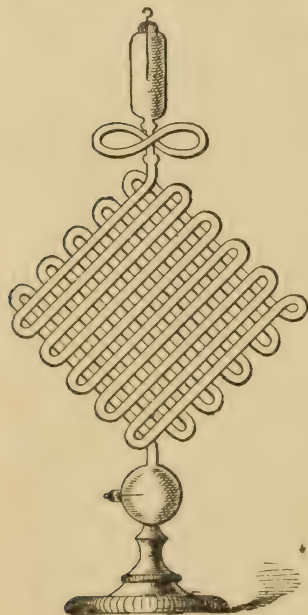
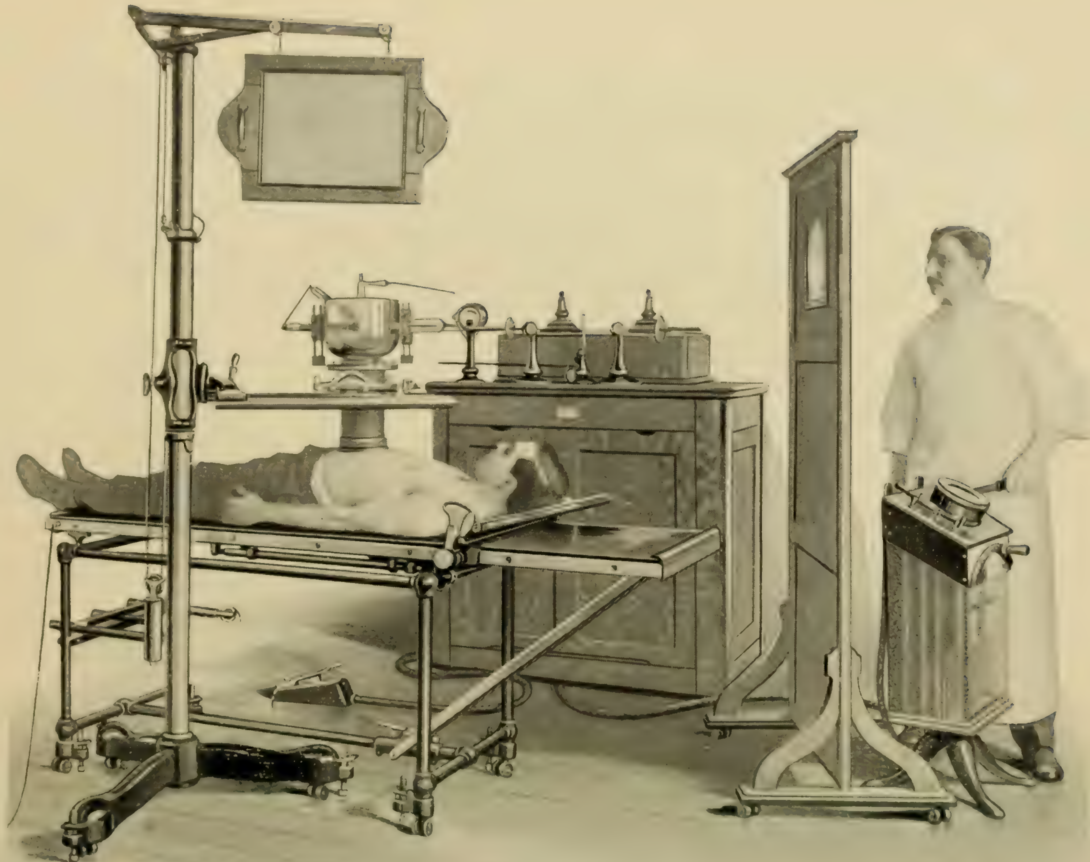


Fig 42
A FANCY GEISSLER TUBE.

What of the glass tubes?

For centuries the scientists have used glass tubes for the study of gases. Thus if we compress air

X-RAY APPARATUS USED IN HIGH SCHOOL LABORATORY.



THE LATEST METHOD OF TAKING A RADIOGRAPH. (Page 225)

sufficiently, it becomes a fluid. This is usually shown in a hermetically sealed tube, and the fluid thus held will exhibit waves incomparably smaller and more sensitive to motion than the waves of water. Now what would be more natural than that Sir Humphrey Davy and the rest should put the arc light in a glass tube and exhaust the air, to see what the light would do in the tube? The moment they did that much, they had a Crookes or a Lenard or a Geissler or a Hertz tube.

Who is Professor Crookes?

William Crookes, of London, was a renowned scientist before the X Rays were found. He discovered the metal Thallium in 1861, and invented the Radiometer in 1864.

What is a Radiometer?

A vacuum bulb made of glass. Inside are paddle wheels or vanes. One side of the vanes is black, the other bright. Take the bulb out of a dark place into the light, and the vanes revolve on their shaft, the bright side always in front. We may call it a light-mill.

What is Anode and Cathode?

The wire that ran into the tubes ended in various ways—with ball, point, or concave mirror—and it was called the anode. It was the positive pole. The wire that ran out of the tube, beginning with point, or ball, or mirror, was called the kathode. Of course, if the current entered the other way, the kathode would become the anode. These points or balls might be as far apart as the tube was big; but when the current was turned on, the tube would show a stream of light passing from kathode to anode, often in zig-zag, serpentine, or other courses. Professor Crookes at last made the bulbs that gave the best effects, putting the anode and kathode at various places, and setting an anode mirror so that there would be a reflection of the kathode light. Dr. Roentgen had placed an aluminium window in the Crookes tube, and found that the kathode rays would go through that, in a Fluorescent way, before he found the X Ray. An auxiliary anode is also used.

Was the light in the Crookes tube Fluorescence?

Yes, it was so considered. You will probably make the comment that Edison's incandescent light is an outcome of the tube idea, and so it is. There the current of electricity is aided in its passage from the anode to the kathode of the bulb by means of the filament of carbon, and the incandescence of the filament gives the light. With the Geissler and Crookes tubes toys and decorations were made, that were admired in the store windows long before the days of the Roentgen ray, and the kathode rays, playing through the glass walls of the tube, were variously believed to receive changes in the glass, such as had taken place in Professor Stoke's canary glass.

What produced the X Ray?

First Davy got the arc light in the air. Then it was flashed in a tube without air. Then the electricians increased the breaks in the circuit from one hundred to say a hundred millions in a second. Then Stokes discovered that the rays of light could be changed or "doctored." Then Stokes, Lenard and others made these rays go through aluminium. Then Roentgen, in doing this, discovered the presence of rays that are not ultra-violet because they cannot be produced outside of a tube, nor with low vibrations, nor with too much vacuum.

What is the X Ray good for?

So far, it has been of great use in surgery, where the conditions of the bones of the hands or feet has been determined before the operation with knife. All bodies of medium density allow the X Ray to pass through them, and new ways of improving the value of the discovery are constantly found.

How is the X Ray usually shown?

A photographic plate is put in its covered case. A cloth may be laid over the case. Any object—say the human foot, in boot and stocking—is set on the cloth and plate. The Crookes tube, of a pear shape, with its stream of Fluorescence to point toward the boot, is placed above the boot. The current is turned on the Ruhmkorff coil from the power-house or battery. The

current goes in the condenser and the swift alternations begin. The boot is bombarded for one hour or more with streams of invisible matter, and after the photographic plate is developed it shows the skeleton of the foot, but no vestige of leather, stocking, cloth, or plate-holder. Sometimes the photograph will show only the iron pegs of the sole of a boot, the leather having vanished. The world, for nearly a year, was unanimous in its expressions of astonishment, and probably no man since Columbus became so quickly famous as Dr. Roentgen.

What did Edison do?

He at once set to work to make some practical use of the tubes and X-Rays. He invented the Fluoroscope (which was afterward much simplified, as may be seen at plate on a preceding page). It was a pyramidal box, its smaller end covering the eyes, and closing them in. At the large end of the box was a bottom or screen covered with calcium tungstate, or a still better fluorescing material, the name of which Edison kept secret. Thus the observer is practically in a dark room, before a screen, on which is a substance that, like phosphorus, will retain light rays. A man's chest is next placed before the screen. The Crookes and Ruhmkorff or Tesla apparatus is placed behind the man's chest, and the current is turned on. The X-Rays develop and go through the man's chest, reaching the screen, where they turn into light on the Fluorescent surface. Then the observer can see the organs of the body in action, and can form theories as to the state of the lungs. Where bullets or needles are imbedded in small bones, the Fluoroscope instantly locates them as well as the photograph, although the surgeons use the photograph, so as to make no personal error.

What else did Edison do?

He coated the inside of the Crookes tube with his Fluorescing material, and the rapid light from the wires caused it to shine with a white, diffusive, and almost cold effect; so that, between Edison and Tesla together, it only remains to obtain a big Condenser that will discharge as suddenly as a little one to get pulsations that will light up the bulb with a white, cold light.

What is Davies' bulb?

It was made in March, 1896, under the direction of Professor Lodge. The anode wire with its platinum mirror was run out from a hollow ball made half of copper and half of aluminium. The electric charge went in by the wire leading to the anode. It leaped into the copper part of the ball. The air was pumped out of the ball. Thus we have a device somewhat like an open flower with a petal. The petal is the anode. The cup of the flower is the cathode. A cap of aluminium fits on the cup. The air is taken out. The charge of electricity comes up the inside of the stem into the petal. It goes down the outside, out of the cup.

What were the results?

This opaque bulb was set going at one side of the laboratory. Sixty-two feet away, a screen of thirty-six square inches was covered with a Fluorescing mixture of potassium platino-cyanide. Midway across the space three feet of timber were interposed. When the X Rays began pouring out of the metal bulb, they penetrated the three feet of timber, and the screen sixty-two feet away lit up. The hand interposed, made no shadow on the screen, so strong were the rays. This stream of force was thrown out of a dark metal ball.

What has been done with blind people?

Blind scientists have been brought to experience new sensations through the X Rays. The object seen appears to be in the brain itself, as the senses have no measure of distance. Edison has made many experiments with blind subjects.

Has harm resulted from the X Rays?

Yes. It is found that the rays have an irritating influence on the skin, and serious inflammation has resulted from exposure to the force.

Describe Edison's X Ray Lamp, as it is popularly called.

The glass tube is made like an egg on a glass standard, so that the "egg" sits on the stem crosswise. The wires enter the "egg" at each end. One of the wires holds a mirror-disk that throws rays upward. The other wire has no disk or mirror

The inside of the glass is coated with the Fluorescing material, and this has been fused into the glass. No X Rays pass beyond the glass in this tube, and Edison believes that their rapid waves

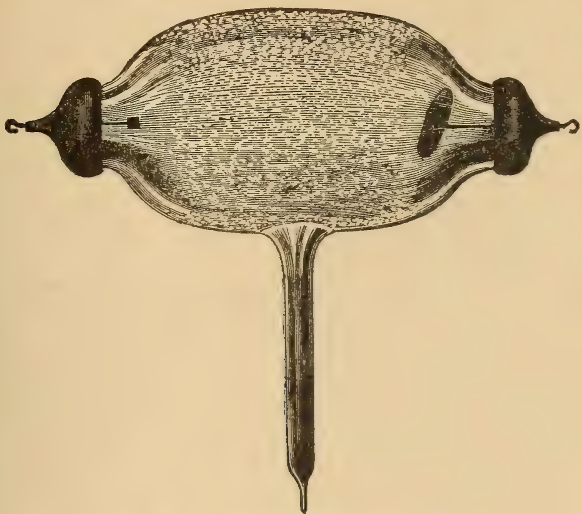


Fig. 44. EDISON'S X RAY LAMP.

cause the white cold light that sets up in the glass. There is but a small expenditure of power, and the economy is nine-tenths as compared with the incandescent light. That is, when apparatus can be as cheaply applied to the Fluorescent light as it is to the arc light, the Fluorescent light will cost only one-tenth as much, and will give out almost no heat at all.

For what is Tesla celebrated? (See page 79.)

For his inventions looking to the breaking and reversal of circuits, whereby these rapid movements can be secured. He is deemed the greatest of all the inventors of vibratory apparatus or oscillators. He was once a workman in Edison's laboratory. With his high frequencies he expects to project Kathode rays in the air from power-houses to lamps at great distances. That is, matter will be projected with force to Fluorescing substances stationed miles from the power-house, and they will become luminous without heat, as phosphorus is at night—or the glow-

worm. Thus the fire-fly and the decaying stump have at last taught their lesson to man.

Is a comet Fluorescent?

Professor Crookes claimed a fourth state of matter—radiant matter—the other three conditions being solids, liquids and gases. There are certain aspects of great comets which could be theorized on the line of a radiant discharge from the celestial ether into the head of the comet. The tail of the comet precedes the comet when it goes out away from the sun, and stars are always seen through the tail. Whether or not such a comet as that of 1882, whose tail extended half way across the morning sky, is a flying kathode receiving the Fluorescent streams of a solar system, can be better determined after the spectra of all earthly forms of Radiance have been compiled and compared.

What was Marconi's discovery?

William Marconi, an Italian, discovered that electric vibrations caused by an oscillator passed through a hill. Subsequent experiments showed that signals apparently could be sent through blocks of buildings in London to a distance of three hundred feet, passing seven or eight walls.

What great things did Marconi soon do?

From the moment of Dr. Roentgen's astonishing discovery Marconi wrought with untiring industry and gratifying success to complete his system of ærography—of telegraphing through air. He sent messages that way entirely across the English Channel. He perfected apparatus which was put aboard steamships and battleships, and Atlantic liners communicated with each other when 200 miles apart on the ocean, conveying valuable information. It began to be generally understood, through the success of these proceedings, that thought-transference, from brain to brain by vibrations not yet understood, or even theorized, are not beyond the realm of human action. Marconi set up receiving-stations at St. John's, on the coast of Newfoundland, and declared that he twenty times received the three dots that made the Morse telegraphic letter *s*, as sent from his sending-

station at Poldhu, Cornwall, at the southwest tip of England. So profoundly did this announcement effect the commercial and financial world that the cable companies, through their officers, sought unsuccessfully to put an end to Marconi's experiments. In the awful Titanic disaster of April 14, 1912, the heroic Captain Rostron, of the Carpathia, through the wireless, saved 706 lives, most of the survivors being women and children. There perished from lack of boats, 1517 persons. Other and frequent examples of life-saving have made Marconi's invention the most highly prized of modern discoveries.

What is peculiar about Marconi's apparatus?

Both sending and receiving instruments are placed at great heights, and it is believed or known that the vibrations or impulses that are sent out follow the curvature of the earth. Like the multiplex-buzzes, the receiving apparatus can be made to respond only to one "sender," and a "sender" may put out impulses which will be caught by one receiver alone, or by all receivers within the sphere of influence.*

Does the world still gratefully remember Dr. Roentgen?

Yes. One of the first of the rich Nobel (see page 253) prizes was awarded to Dr. Roentgen early in 1902. This action was intended to distinguish him as one of the greatest living benefactors of his race. The scientists still say "Roentgen rays" and use the terms "Roentgenize," "Roentgenism," etc.

What is Bell's Radiophone or Photophone?

It is a union of X Rays, search light and telephone. We have seen that Fresnel and others learned how to project light so that it would not disperse sidewise or laterally. It is now believed that a ray or a volume of light could be sent around the world if the volume were caught at intervals and corrected to the cur-

*The feeble ether-waves are made recognizable in somewhat the same or similar way that the semaphore operates in the Block-Signal (page 106.) A slight molecular action of silver and nickel (in the "coherer") enables a waiting current of electricity to pass through and give audible expression to the far more occult action of Marconi's mystical forces. Because the particles of silver and nickel cohere as the Marconi waves of ether strike the particles, thus making a bridge for the waiting electricity, the instrument was called a "coherer" by Calzecchi, who invented it, and the name was retained by Branley, who improved it. In the Block-Signal, however, a feeble current of electricity acts as the trigger for the compressed air force. In the "coherer" a feeble ether-action, unseen and unheard, not detectable except by the ever-watchful; force of electricity acts as the trigger goes over, and allows the electricity to make the sounds or motions that can be heard or recognized.

vature of the earth—that is, a row of search lights fifty miles apart would need only one electric light in order to throw a shaft of light around the world.

How did Bell find that light would carry sound?

By means of a cell of selenium, a costly metal, (one of the elements—see Chemistry.) When a ray of light fell on the metal, a telephone connected with the metal gave out a sound.

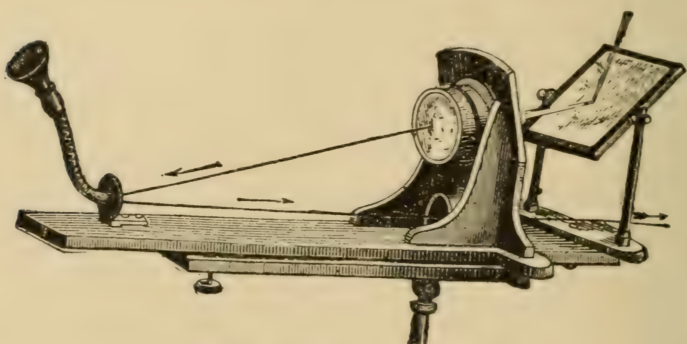


Fig. 45. BELL'S RADIOPHONE.

Afterward he found that lampblack was as good as selenium. The ray of light from a mirror strikes the selenium. A wire leads out of the selenium into a telephone. Now if the mirror is on the other side of a diaphragm or disk, against which a man is talking, the rays from the mirror carry the tone and words of his voice, and this has been done at a distance of a mile and a half. Furthermore, it is the X Rays that carry the voice, for matter may be placed in the line of the ray, apparently cutting off communication, and yet the voice will be heard just as well. An india rubber disk failed to stop a message. The light must be steady. In recent years Marconi has sent messages and music by *telephone* over long distances by wireless.

Compressed Air.

What was the first pneumatic invention to attract general attention in America?

The Westinghouse Air-Brake, by which the locomotive engineer could apply all the brakes of a railway train. This machine was invented and improved by Mr. Westinghouse, and, after twenty years, was generally adopted by the railway men of the world. In the center beneath each car is a cylinder, with a piston extending from each end of the cylinder. Air goes in, the pistons go out, the brakes are applied, the air is let out of the cylinder and springs throw the pistons back, ready for another application. A secondary cylinder of Compressed Air is always ready, close by, to give instantaneous force to the pistons. Taking the pressure off the hose or pipe that goes to the locomotive from the brake lets the air out of the secondary cylinder and applies the brakes, so if the train severs itself the brakes apply themselves. Therefore the device is called and is at times an Automatic Brake. The series of cylinders and brakes are all connected through a "triple valve," on one pipe that reaches an air-tank on the locomotive. The air-tank is filled by a little steam-engine on the locomotive, which you very often see going while the locomotive is standing at the station. Air-brakes are used on electric railways and the pump is operated by a separate motor. A dial in front of the motor-man records the air pressure.

What is the Pneumatic Tube?

An ingenious and useful system in operation in populous cities, and in large establishments elsewhere. By this method,

small packages are almost instantly conveyed over considerable distances. A system of brass tubes with no right angles underlies the streets. The central station is usually at the main telegraph office. Here a row of closed glass cases guards the entrances to the various tubes. The name of the newspaper or other establishment to which the particular tube leads is on the case. The pouch which is to pass through the tube is a cylinder made of leather, and is less than a foot long. The telegrams or letters are inclosed in this pouch, the pouch is set on end in a movable pneumatic car, and the car is pressed forward into the Pneumatic Field, which leads to the tube. As the pouch reaches the tube it is sucked or driven in, and a few seconds later is at the newspaper office. Communication between any two offices can thus be made very rapid if a trusty servant operates the central station, where a change must be made. Systems well worthy of the name were in operation in 1897, in Philadelphia, New York and Chicago. The Philadelphia tubes are six and a half inches in diameter.

What is the Electro-Pneumatic Block Signal?

The railroad is divided into "blocks," or sections, and no train is permitted to enter a block in which there is a train. If there is a train in the next block, a red light, or an out-stretched wooden arm or semaphore, warns the engineer or motor man, and he must come to a stop till the red light changes to green, or the wooden arm falls. Air-compressing engines are situated at the railroad shops, and a large storage tank stands near by. From this tank a large supply pipe runs the whole length of the track. Branch-pipes, with valves, lead to the semaphores. A section of track is electrically wired together and a well-battery is sunk in the ground at each block. The current goes up one rail to the end of the block and returns to the battery on the other rail—that is when there is no train on the track. When there is a train, the current crosses through the train and gets back to the battery the shortest way. At the semaphore is a compressed-air cylinder, like the Westinghouse. This compressed-air cylinder is operated by electro-magnets and springs that are released by electricity from additional batteries. When

the batteries are operating, the arms are pulled down, and all is well. When they cease to operate, or when a train comes on the block and the track current is shortened, a weight carries the arm of the semaphore outward, so that it commands the following engineer to stop. Sometimes two semaphores on one post show the condition not only of the block just ahead, but of the block beyond that. The top one is red, the lower one green. All this action is automatic. If the signal does not change in so many minutes the engineer may proceed with caution.

Where is the leading Compressed-Air power-house?

At Paris. There Victor Popp has for many years furnished power for pneumatic clocks, of which there are at present about two thousand in the city. About ten thousand horse-power of energy is generated at these works. Power is furnished to refrigerating establishments, street-cars, dynamos, and other machinery. Pipes are laid under the streets and Compressed Air is measured to the customer by a meter, like gas.

How is air compressed at such a power-house?

By a steam cylinder and a piston which unites the chest for the Compressed Air with the steam cylinder, one rod acting as a

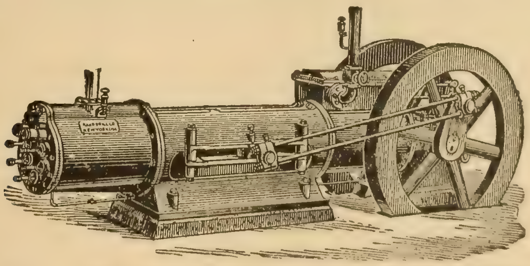


Fig. 47. THE RAND DIRECT-ACTING AIR-COMPRESSOR.

piston in both of the cylinders. A pipe leads from the air-chest to the storage-tank. Service pipes lead from the tank into the streets of the city. The pressure is about seventy-five pounds to the square inch.

Where has Compressed Air taken the first place as a motive power?

In the mines of America. The Hydraulic Power Company of Michigan, sends air in pipes from the Quinnesec Falls to Iron

Mountain, to drive all the machinery of the Chapin and Ludington iron mines.

What is the Compressed-Air Rock-Drill?

It is a small machine that is braced against an adjustable iron column which binds against the walls of the shaft or tunnel in which the rock is to be removed. The air hose may lead down

Fig. 48. ROCK DRILLING WITH COMPRESSED-AIR.

the mine three-quarters of a mile or more. By means of this Drill holes are rapidly bored, and when enough are made the blast is set off. No other form of power has equaled Compressed Air for these subterranean purposes. The great Sanitary Canal, from Chicago to the Illinois River, has been cut through miles of lime stone by means of the Compressed-Air Rock-Drill. The steel drill is revolved by machinery, as air and steam will work in the same way; but air has the advantage that it will not

condense into water as steam must do when it is below two hundred and twelve degrees of temperature.

What is the Compressed-Air Painting Machine?

It was invented by C. Y. Turner, for use at the World's Fair of 1893. Some of the buildings were so large that they could not have been painted by hand in the time required. The paint was put in tubs. The Compressed Air drew the paint into a hose and drove the paint through an atomizer with such force that the paint was put on and into the wood better than it could be done by hand, and with astonishing results economically. The machine moved on wheels. Since the World's Fair, the steel works have employed this device for painting railroad bridges and building material.

What is the Compressed-Air Calker?

It is a machine, used notably in the Cramp Ship Yards at Philadelphia, where armored cruisers are made for the United States Government. All the calking of war-ships is done by such machinery, and one calker does the work of four men. It strikes four thousand blows a minute. A nearly similar machine is used by the stone and marble cutters. The engine is in the handle of the tool.

What is the Vacuum Cleaner?

It is a machine that, beginning in the passenger car yards of the great railroads has vanquished the world. Late models of carpet sweepers, for instance, are ingenious in construction and wonderful in effects. Great sanitary advantages are obtained in the household.

How does a Compressed-Air Locomotive look?

Very large and cumbersome, more like a double oil tank-car than anything else. The steam-chests and drive-wheels, however, copy those of an ordinary locomotive. In France, between Paris and Nogent on the Marne River, they are charged for five mile trips and re-charged every mile and a half. A similar railway is running at Berne, Switzerland.

What is the Asphalt-Refiner?

Asphalt, for street-pavements, comes from Trinidad in a crude

state. It must be boiled and well stirred. A cauldron like a soap-boiler is lined with pipes, but instead of steam alone, they also carry Compressed Air, which is sprayed from holes in the pipes. After three days' boiling, the mass has become homogeneous, and will harden properly for use on the streets, where it makes the best pavement that has yet been devised for city use.

What is the Air-Gun?

It was at first an exhibition-affair, shooting a feathered shaft, for pleasure-seekers at fairs. It had its beginning in the child's pop-gun. It is at last a great pneumatic cannon, invented by Lieutenant Zalinski, which throws a torpedo two miles and a half from a steel tube sixty feet long. High explosives cannot be projected with ordinary gunpowder, because they will not themselves endure the great initiatory shock. By the aid of Compressed Air, the projecting force increases with the journey of the projectile toward the muzzle of the cannon. It is understood, however, that powder will eventually displace the Compressed Air.

What is Wood-Pulp Silk?

A fabric woven in France. The wood pulp is chemically treated until it has become a gelatinous substance. It is then inclosed in a tank to which Compressed Air is introduced. This tank forces the pulp through a filter and into a second tank, out of which lead hundreds of glass pipes, whose tubes are each no larger than a silken fibre. The pulp issues from these holes in a thread, and six threads are woven into a strand of the silk. (See Silk, in Clothes.)

What is the Coal-Dump?

By this device, one man can feed coal to a battery of steam boilers however large. The cars are loaded, sent to their journey's end, dumped into automatic feeders, and returned for another load, all by the turning of a valve by a man who may retain his seat in a chair. The automatic chain feeders are displacing coal-shovelers in the furnace-rooms of the ocean steamships. Cars on the Sanitary Canal were dumped by air-pistons.

How Does Compressed Air rival Electricity?

In the convenience with which it may be transmitted. It is more safe. It is more easily understood, and does not arouse the fear and prejudice of the human race. It can be installed as the means by which every part of the work of a great factory may be carried on, as at a large machine shop in St. Louis, where a twenty-ton crane is moved. Shafting and bands are abolished, and each considerable machine has its own motor, fed by a hose. Water supplies for cities may be aerated, as at Little Rock, Ark. The pneumatic tire, on the bicycle, has brought the subject home to the people, and we have shown that the Council of Experts, at London, hesitated between Electricity and Air as the proper vehicle to use in transferring the power taken from the turbine wheels at Niagara Falls.

Is Compressed Air one of the so-called Prime Movers?

No. Neither is Electricity. Yet a prime mover, such as steam, in certain places and altitudes (as at pages 83-87) or in deep mines, may be less useful and even less economical than secondary power. A prime mover, too, in certain places, may be impracticable. Steam itself is a varying factor: Water boils at 212° sea-level; Dr. Hooker boiled it on a Himalayan peak of 18,000 feet at 180°. Under the suction of an air-pump it may boil at 76°. On the contrary, under 50 atmospheres of pressure, steam will not generate under 510°. For many reasons, of course, it is inadvisable to operate a steam engine at great altitudes—the extreme cold, the rapid evaporation, the low heat of the vapor, the expense of fuel, etc.—and compressed air has been successfully used in recent tunneling operations. But, where electric power has been developed, Electricity seems to have forged ahead in the race for precedence as a secondary mover.

PLANTING RICE IN JAPAN.

Grain, Etc.

Is Bread the commonest of food?

Yes, and it is ancient beyond the scope of history. In the earliest poems of the Bible the maidens are represented as sitting with mill-stones on their laps. In the English of England wheat is called corn—that is corn means *grain*, and the people apply the term to the leading grain of their region. Thus the Scotchman calls oats *corn*. The settler in America, finding that Indian maize was seemingly best fitted to this climate, called maize *corn*. English settlers in Egypt and India have called rice *corn*, on the same principle. In reading the foreign press and dispatches, and the Bible, it must be remembered that *corn* nearly always means wheat. This grain, as we see it today, was as well known to the Pharaohs of the early dynasties, and wheat that had been inclosed in tombs for five thousand years was sown in the Botanical Gardens of Bath, England, in 1842, and grew fifteen or twenty bearded ears on each root.

How was Wheat ground into flour?

First by lap stones, then by revolving mills on larger stones; then the revolving stone was run by machinery. For ages, and until the 'seventies, the revolving stones, called buhrs, generally operated by water-wheels, were the means of making all the flour that was used by civilization. In 1877, the roller process was copied in America from European mills, where it had been recently invented, and the old-time mill by the stream, with its rumbling shafts and stones, began to pass away.

Describe the modern process.

Wheat from the car or vessel goes at once to the top of the

mill. When it reaches the ground again it is in the form of Patent or best-grade flour, screenings, "offal," that is, bran and shorts, "clear" Flour, and first and second grade flour. The same bushel of wheat has produced these results, but the various grades of wheat have been through different series of machines. From the bin at the top of the mill the wheat falls past a blast of air, which carries away chaff and light dirt; next it strikes three sieves that catch the grains of corn, oats and rye. At a fourth sieve the wheat grains are themselves too large to go through, and they are thus separated from small seeds and pieces of dirt. But there is one seed that stays with the wheat despite all sieves, and that is cockle. So a drum was invented, and in this drum there are indentations the size of a cockle and too small for wheat. As the drum goes around, with wheat in it, the cockle fall into the little holes and are carried upward; as they pass overhead they fall on a catch-board in the drum. The drum slants and the wheat slides through slowly. Next, the wheat passes through a drum in which a wire brush revolves with high speed, creating also a strong air-blast. This process takes away all fuzz from the kernel, and even wipes out the crease, leaving it clean. As the stream of wheat leaves this drum it pours over an electro-magnet, which attracts all particles of iron, such as wire, or harvester and thrasher belongings.

Is it now clean?

Yes, and that is the main difference between the old and the new methods. The clean wheat is now to pass through grooved iron rollers, one of which goes faster than the other. The lines or strings on these rollers are like those on a screw, and the wheat is broken lengthwise. The first set of rollers is comparatively coarse and set far apart ; the series progresses in fineness. A very little "break flour" results, of a cheap grade. Next we come to the centrifugal machines, so when you hear of centrifugal Flour you may know the source of the term. The crushed wheat goes to the centrifugals to be "scalped." The wheat is poured on these reels, and they, by rapidly revolving, dash it away from their centers, casting it against wire screens and silk gauze, and grading it according to the size of the mesh

through which it escaped. It is now middlings. A German machine called a plane-sifter, by eccentric motion and jarring, does the same work with less force.

What is the Middlings Purifier?

It is a blast of air. Before that blast the streams of variously graded middlings pass, and the bran is blown into its own receptacle. The process now begins all over again from the rollers or crushers, and is repeated until there have been five operations. The flour then goes into barrels or sacks. The bran, however, after getting into the air blast, is passed through a machine which brushes it in search of flour.

I have heard of mill explosions. What are they?

There was an explosive force in the flour dust, either when lighted by a flame, or under certain kinetic (or moving) circumstances. It is believed that the modern ventilating fan, by revolving, draws this dust from the air in sufficient quantity to render the repetition of these calamities impossible. The flour is collected in a chamber, and is sold as a cheap grade—a warning to the buyer who values his health.

Has flour or middlings eome to be used for other purposes?

Yes. The iron foundries of a large city use about two hundred barrels daily for mixture with sand in moulding. In years of scarcity in the corn crop, wheat is fed in prodigious quantities to animals. In the corn-famine of 1894, the Government Bureau estimated a consumption of eighty million bushels for this purpose. In a large city about sixty barrels are daily made into paste. The bread and pastry bakeries use more flour each day than the city households, and five hundred barrels a day are made into crackers. China is now buying our flour. The meat-packing industries of America do not approach the value of the milling industries by $80,000,000 a year.

What is Yeast?

Foam, froth, spume. Shakespeare speaks of the yeasty ocean. Yeast is described by the chemists as "an insoluble substance forming an essential component of all sacchariferous juices

when in the state of vinous fermentation." Again, yeast is a substance which is added to the dough of bread. If allowed time, it will produce alcohol and carbonic acid from the actual or possible sugar present in the dough—for starch is capable of turning into sugar. The flour is made up of starch and gluten. The gluten forms a sack or cyst or hollow ball in which the carbonic acid gas is held, and as these cysts swell, the bread grows lighter. In the earliest historical times the yeasting principle had been applied to dough, by keeping over wet yeast from baking to baking. But doubtless the feast of unleavened bread, when the Jews were compelled to destroy all leaven, was instituted in order to secure new and purer yeast. This hold-over yeast is called leaven, but is yeast. The Germans were the first to make the ferment, reduce it to a paste, mix it with starch to still further dry it, compress it, and put it on the market in cakes. Next the process went to Scotland, and is now general in the United States, although many men and women are inclined to believe that the old hop-raisings, which were kept wet in an earthen vessel, produced more highly satisfactory results. (See Catalysis.)

What is Vienna Bread?

We may group as "Vienna" or "French Bread" all loaves that aim to give a maximum of crust, and to throw a quick crust around themselves as they enter a brick oven. As the loaf goes on the bricks or soapstone, it is called "bottom" bread by the bakers. The long slim loaves are wrapped in canvas bagging while they await the oven. Then they are unwrapped and placed on the baker's "peel" or paddle, where the baker gives them the three slits with a razor, and paints the tops with a corn-starch liquid which gives the loaf its reddish tint. Steam

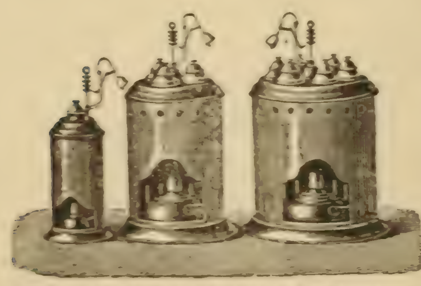


Fig. 50. KUNI'S APPARATUS FOR TESTING THE BAKING VALUE OF FLOUR.

is admitted into the oven. The steam gives a thick crust, which holds in the gases, leaving them to escape only at the slits, and the way to know a good loaf of Vienna is to see that the baker's slits did not heal in the oven, but remained broken open by the escaping gas.

Is there anything peculiar about a baker's brick oven?

Yes. It is circular in shape and about fifteen feet in diameter. The bottom is made of soapstone, and is a circular disk, moving on its center by machinery. It holds about three hundred and fifty ordinary baker's loaves in pans, and these loaves are baked by being carried around slowly over the fire for half an hour. Each bakery makes from fifteen to twenty different kinds of pan bread, but there is little variance in the dough, which is kneaded by machinery. The wagons carry out the bread about three o'clock in the morning, and return with the unsold loaves of the day before, which are sold at the bakery to thrifty people for two cents a loaf.

What other grain is used very largely for bread in America?

Corn. It is ground into meal, and this meal is used as a "bread-timber" through vast areas of the country. There is no yeasting process. The bread is often improved by the introduction of one-third wheat flour and some baking powder. Corn contains a fair amount of gluten and more vegetable fat than any other familiar grain. It is a heating food. For pan-cakes, or hoe-cakes as they are often called, corn seems especially well fitted, and even in the cities of the North, at the modern lunch-counters, corn cakes make a large item in the day's business. Corn "gems" or buns are also popular. Mush and milk, or pudding and milk, made by stirring sifted corn meal in boiling water and serving hot in bowls of milk, offers one of the healthiest of foods where the bad effects of little or no exercise are felt. Mush and milk are remarkable for satisfying the appetite quickly, but for only a short time. Green corn is canned in vast quantities. The corn crop of America is its principal production, and it is said of it that not five per cent. of it leaves county lines. The crop has run over two billion bushels for two years at a time. Corn is the principal crop of

Mexico, and may almost be called the standard of value there, for nearly all mining enterprises depend for their cost on the yield of corn in Mexico during the period in which the labor is done.

What is hominy?

The word is a corruption of the Indian *auhuminea*, (parched corn). It is hulled corn. Dry corn is boiled in lye until the hull is eaten off, and the eyes begin to come out. It is then washed several times in cold water, and boiled in water with salt. It is eaten in milk or fried with pork gravy. "Hog and hominy" are twin dishes in the Southern States.

What is corn-oil?

It is pressed out of the germs or hearts of corn at the glucose factories. It is used as a salad oil, and is sold to soap makers and paint mixers.

What is corn-oil cake?

It is the residue of the corn germs or hearts after pressure in which the corn oil is secured. It is exported to Europe.

What is gluten, as sold on the market?

It is the residue of corn after the germs and the starch have gone from it. It is pressed into wet cakes, dried, powdered, and sold for cattle feed at a good price. It is a gray or yellowish coarse meal or flour.

Is Rye also used for bread?

Yes, more and more, as Europeans have immigrated to America. Rye forms the great crop of Russia, over 700,000,000 bushels being harvested in a year. The rye loaf is very dense and damp. It is sweet and does not grow stale as quickly as wheat bread. For this reason it is prized by German saloon-keepers, and others who deal in free lunches. Many persons of foreign birth like aromatic seeds in the rye loaf. Rye grows taller than wheat, and the farmer often goes through his field before harvest, cutting off the tall heads, that ripen a little later than the wheat. The kernel is long, slim and dark. It does not present that edible appearance which is characteristic of the wheat berry. A large part of the American crop is used in the

distillation of whiskey, and this brand of liquor is held in high esteem by druggists.

Is any other grain largely eaten in America by all classes of people?

Oat-meal, or rolled oats, or prepared oats may be considered a growing staple breakfast food—at least in all large cities. The kernel has been divested of its husk and partly broken. It is put in water and boiled as glue is boiled, with one vessel inside another, the outer vessel containing boiling water. The paste thus prepared, is eaten with sugar and milk or cream. Children readily use this food, and doctors have favored it. In Scotland, oat cakes are eaten very generally.

Fig. 51. THE RICE PLANT.

What is Rice?

The seed or grain of a grass called *Oryza sativa*—possibly the *wheat* of the ancients. It forms the chief article of food for one-third of the human race, and is fermented into the leading liquor—*saki* (sah-kee)—of Japan and the *arrack* and *shou-choo* of the East.

Where is it grown?

Rice is raised (as we raise wheat and corn) in China, India, Japan, Ceylon, Egypt, Italy, Spain and the Southern States of North America. It must be sowed in a muddy or flooded soil, and is often transplanted to drier ground. In the Southern States, where the best rice of the world's crop is raised, the seed is drilled in, as in a wheat-field, and the field is flooded to the depth of several inches. Then the water is drawn off. Later on, the water is let in again to kill weeds. When the harvest is nigh the field is flooded once more.

THRASHING RICE BY DRAWING THROUGH A FRAME SET WITH WIRE TEETH. OKUMURA VILLAGE, JAPAN.

THRASHING RICE IN TEXAS.

AGRICULTURE'S LATEST TRIUMPH IN THE CORN-FIELD

What peculiarities has Rice as a food?

It exceeds all other grains in the proportion of its fat-forming and heat-giving elements, and is adapted to the needs of the people in hot climates.

How is Rice used in Northern climates?

It is good for puddings and is put in soups. A favorite table use of rice is to serve it in place of potatoes with stewed chicken

Fig. 53. TRANS-PLANTING RICE.

or any stew that furnishes a large amount of sauce. Rice may be eaten by invalids after serious illness in the intestinal tract, but it cannot be said that it plays an important part in the households of the American people, except in the Gulf States.

Give me some idea of the effect of climate on the cereal crops and their use.

We find oats and barley growing in the far north, like Canada, Scotland and Norway. In those countries the cakes and porridges to be made from these grains are sought and relished from habit and heredity. The next great crop going southward is rye, which as we have shown is a real competitor with wheat for the favor of half the Christian world. When we arrive in

climates where it is hot in July and August, wheat is the staff of life, and it grows by special care in many other regions, for there is a wheat harvest somewhere every day in the year. In the hot dry regions, corn is king. It was first called Turkish wheat, and was not originally found in America. When the climate becomes both hot and wet, rice and millet become the chief care of the people, for it is there they must obtain their farinaceous food. Rice is like oats, but is what we would call a water grass, or at least it must start in water. The impressions of Northern people regarding rice are borne out by scientific analysis, for rice is found to contain little gluten or sugar, the principal parts of bread.

What is Millet?

It is a grass seed filled with gluten, and is the smallest of the cereals raised for food. It is called Dhurra in Asia, and forms the chief breadstuff in Central India, Arabia and many parts of Africa, but is gradually being displaced by wheat in India. In the Northern States of America it is heard of only in the hay market.

What other great food is borne on the stems of plants?

The banana or plantain. If we take all kind of bananas they may perhaps be claimed to be the leading food of the world, and it is said that they offer sustenance to 800,000,000 people. The consumption of bananas in America has grown enormously of late years, since their nutritious value was proved by invalids and children. Were the cost of transportation and distribution less, their use would be vastly increased. Where parents desire to feed bananas regularly to children that are not eating well, the cost of a dollar or more for a bunch or limb makes the banana more a medicine than a food. The city parks usually keep banana trees in their conservatories, where the big plantain may be seen, with its bunches of bananas hanging with the bananas pointing upward in a very uncomfortable posture, to those observers who are used to seeing bananas only in warehouses or fruit stalls, hanging the other way. The bananas we get are all plucked very green, and ripen on the way or in the warehouse. The red bananas that look so luscious are in reality less palatable

than the white or yellow ones. Gluten and starch are the main ingredients, and when the banana is fully ripe the starch has become sugar. In hot countries, the principal eating is done early, and bananas should not be consumed at night.

Is Barley used largely as food?

Not in America. Barley cakes are eaten abroad. The hotels and restaurants serve it in soups. The American crop is about sixty million bushels, and the world's crop is nine hundred million bushels, so we may get some idea of the world's taste for beer, as the main part of this yield goes to the top floors of the breweries.

What is Sago?

It is the starch of the sago palm, and is derived from the pith. The sago palm grows in Africa and the East Indies. One tree often yields five hundred pounds of commercial sago. The logs are split and the pith is taken out. This is pounded in water, and the starch settles on the bottom. After several washings, the paste is strained into small grains. Its use is for a dessert pudding. After soaking all night in water, milk, eggs, salt, sugar, and flavoring extract are added, and the vessel is placed in an oven where the sago is baked slowly and served hot or cold, with or without cream or milk.

What is Tapioca?

It is a starch which is used in the same way as sago in the United States. It is from the same plant as cassava, which grows in South America, the West Indies and Africa, and is called the Brazilian Arrow-Root, or Manioc—the Jatropha manihot, a native of Brazil. The roots are peeled and reduced to a pulp. The prussic acid is squeezed out or evaporated and a powder free from poison is secured. Cassava bread is made from this powder, forming an important article of food to the negroes. Tapioca is the starch of the powder, dried on hot plates, and self-formed into the little granular masses that never entirely depart from the food. Tapioca pudding may be prepared like sago, or it may be made with milk instead of water. Apples are often added, and sometimes slices of orange. It may be eaten with cream. Good tapioca pudding is not

CLEANING AND GRINDING RICE. YOKOHAMA COUNTY (GUN), JAPAN.

easily made, as the masses or granules require skillful treatment or they will remain heavy to the taste.

What are Spaghetti and Vermicelli?

They are two sizes of Macaroni—flour tubes that form the favorite food of the Italians and have come to be regarded with high favor in French and American restaurants. Usually the size is Vermicelli (worm size.) This is boiled, and served with tomato sauce and grated cheese—Parmesan cheese (from Parma) most often. Factories have been established in America, where Macaroni is made both in the old and the new way. Hard white Minnesota or Northern wheat is bought, washed and dried. Then it is cracked and polished into what is called "semolino." In the modern factory a hundred pounds of the semolino are put in an iron mixer, which has a shaft from which project round steel bars. Hot water is added, and the broken wheat is worked into a dough, which grows stiff slowly. Next the dough goes under the rolling machine, which is a granite wheel weighing several tons. This wheel goes around in a circle, traveling over the dough. This is a rolling-pin on a large scale. It leaves the dough in a shining condition. The kneading machine comes next. Here the bed goes around, and the dough thus passes under conical cog-wheels, that serve as knuckles. This lasts half an hour, and the dough is ready for the cylinder press. This is a steel box like a locomotive's steam-chest. A piston comes down on the dough with a heavy pressure. In the bottom of this cylinder are holes the size of the Macaroni wanted. In the holes are cores held by pins. The dough passes these pins and joins its sides afterwards, so that though it does not come out of a ring it still presents itself as a tube. The Macaroni as it hangs from the cylinder, is cut in lengths of ten feet, carried to the cutting table, cut again to box lengths, and then dried for eight days. The original American and English Macaroni was called noodles, and the noodle soup of the present day is made with Vermicelli. The letters of the alphabet are also cast in dough, and make a common and interesting ingredient of hotel and restaurant soup.

Are there any native starch puddings?

Yes. Corn starch is used more largely than either tapioca

or sago. All baking powders now in use are more than one-third starch. America produces 500,000,000 pounds of corn starch, 2,000,000 pounds of wheat starch, and 30,000,000 pounds of potato starch. Wheat starch is used in the fine laundries. The largest consumers of starch are the paper makers, the carpet weavers and the makers of cotton and linen cloth.

How is Corn Starch made?

The corn is cleaned under an air blast. It is then soaked in warm water, which is changed. In three days the corn is pulpy. Next it is ground in buhr-stones, in the old-fashioned manner, except that a stream of water is always passing through the stones. The milky water runs toward sieves where the bran and corn-germs remain behind for cattle-feed. The starch-milk now runs down inclined planes, and as it is insoluble in cold water, it sinks to the bottom of the stream, like sand. This sediment is secured and washed over and over again. It is then molded into blocks about six by eight inches in size, which are baked. The heat draws out a crust of impurities, which is scraped off by boys and girls. After scraping, the blocks are put in the drying room, where the steady but low heat causes them to break into the irregular masses which are sold in the trade. The fine brands are ground or pulverized for the market. The irregular crystals of the old time starch are seen no more, or rarely. Corn yields twenty-four to twenty-eight pounds of starch to the bushel. Wheat starch is made in the same way.

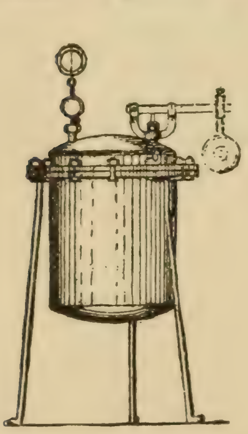


Fig. 55. DIGESTOR FOR STARCH DETERMINATION.

What is Buckwheat?

It is a plant which raises a seed like a beechnut—that is, triangular in shape, and our word Buckwheat comes from the German *Buchweisen*, or Beech-wheat. A vast quantity of Buckwheat is used in the United States for griddle-cakes. The bees favor a buckwheat field, and its yellow blossoms tell of the

yellow dye-stuff that the plant produces. In Asia, similar yellow dye-stuffs are used both for food and medicine. The buckwheat breakfast griddle-cake is a winter dish, remarkable for its lightness, and the rapidity with which it can be cooked. It is a feature of the modern cheap lunch counter in large cities.

What are Crackers?

In Europe crackers are biscuits. Biscuit means *twice cooked.* In America, the term Biscuit is applied to small pieces of regular bread or to small pieces of bread-food that have been quickly fermented by means of baking powder. There are hundreds of different kinds of crackers, but we are accustomed to three main styles—first, the round cracker that comes in barrels and is about the size of a silver dollar; next, the big square thin soda cracker; lastly, the little oyster cracker, the size of a thumb's end. Plain water crackers and ship biscuits are harder and simpler in make-up. The cracker is usually made largely by machinery. The dough-mixer is cylindrical, with revolving arms inside, like the macaroni mixer. The dough is rolled out like paper, the crackers are cut by machinery, and a wide traveling band carries the pans into which they have fallen on an endless chain through an oven nearly forty feet long. They are usually subjected to great heat, so that the flour in a barrel of crackers weighed more before it was baked than afterward—that is, some of the water is dried out of the original flour as it came from the miller. In the civil war of 1861–65, the soldiers called their crackers "hard-tack."

Name some of our crackers and cakes.

Butter Wafers, Sea Spray and Pearl Oysters, Soda Biscuits, Club-House Wafers, Crystal Wafers, White Wings, Indian Gems, Graham Biscuits and Wafers, Oatmeal Biscuits and Wafers, Toast and Milk Biscuits, Pilot Bread, Arrowroot, Albert and Abernethy Biscuits, Afternoon Teas, Animals, Alphabets, Anise, Assorted Cookies and Jumbles, Almond Macaroons, Long Branch, Chocolate Wafers, Cracknels, Coffee Cakes, Cocoanut Bars, Fig Biscuits, Fig and Honey Bars, Frosted Creams, Ginger Snaps, Grandma Cookies, Honey Fingers and Jumbles, Lemon Creams, Snaps and Wafers, Marshmallow Eclairs, Murray

Squares, New England Wafers, Orange Blossoms and Crisps, Pretzellettes, Raspberry Tarts, Snowballs. Sultana Fruit, Spice Nuts, Square Meal, Vanilla Squares and Wafers, Wine Biscuits, Cracker Meal, Imported German Wafers, variously scented, in tin cans, English scented Biscuits in cans, Dog Biscuits, Whole Wheat Wafers, Gluten Wafers, three grades of Oatmeal and of Graham Crackers. Every first-class city grocery is expected to keep all these and all the newly advertised brands on sale.

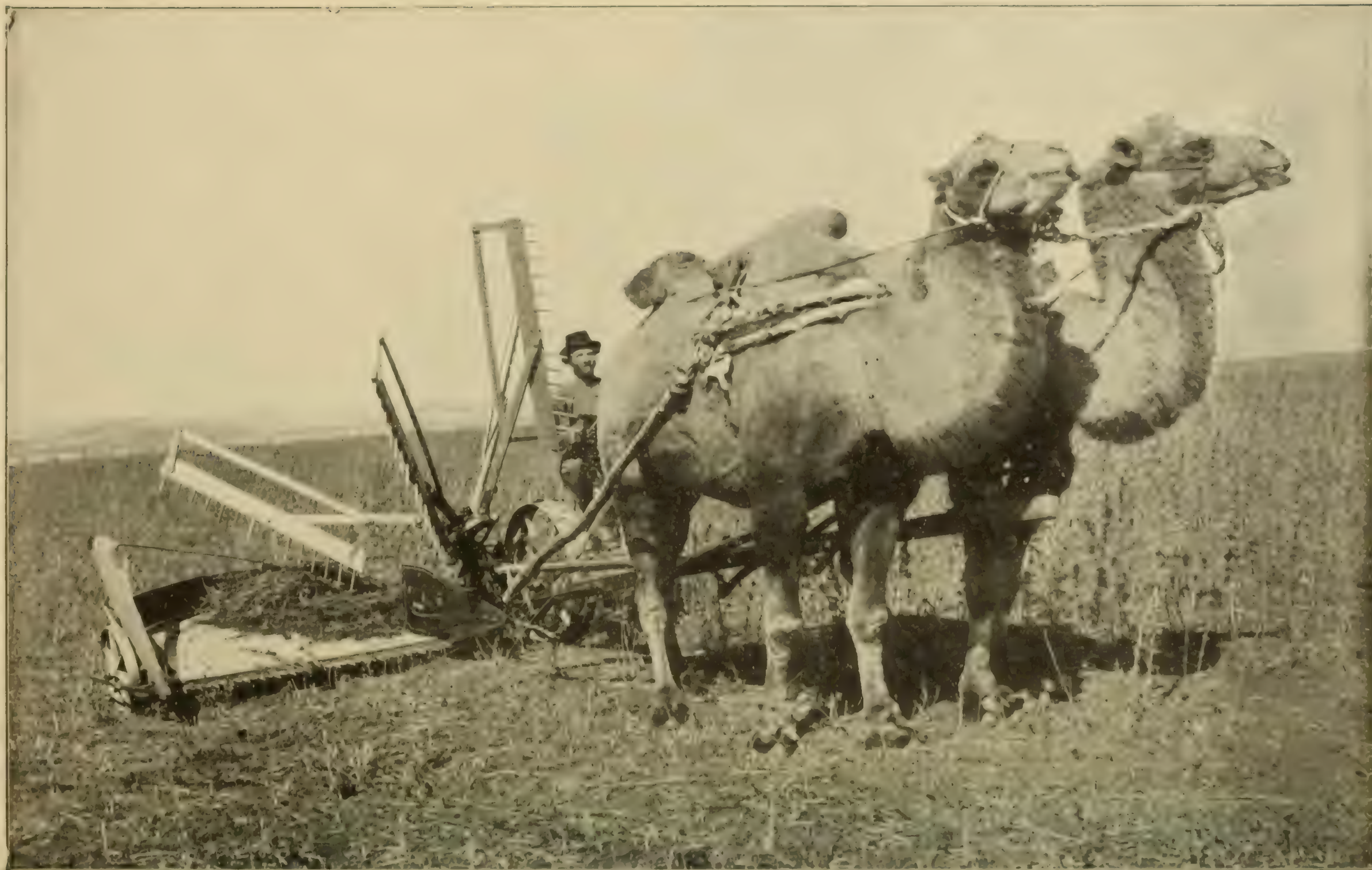
What is Baking Powder?

It is a modern ready-made mixture of the acids and alkalis that were used by our ancestors to produce a quick rising in dough. [See Chemistry.] The wars of baking powder companies, whereby each one endeavored to show that all the others used ammonia, have brought these institutions prominently before the people, but to the active housewife they are all well known on their own merits. A large city uses three million pounds of baking powder a year. Baking powder is composed of cream of tartar and soda, with starch added to keep the twain apart until they are wet in the dough. When wet, they generate carbonic acid gas, like yeast, and the dough "rises." Cream of tartar is a white powder or crystal, which is made from wine settlings, or "argals." Crusts of tartar form on the casks, hence the name of "cream," Beside its tartaric acid, it contains some potash. Soda is the carbonate of sodium, and sodium is one of the two principal alkali metals.

Where does the word Alkali come from?

From the Mediterranean sea-weed which the Arabs called Kali, and the ashes of all sea-weeds furnished the earliest source of the soda of commerce. Now it is produced more cheaply by the decomposition of common salt. Salt is burned with sulphuric acid, and then with chalk and coal. The mass is then soaked, dissolved and again roasted until it becomes the soda of our baking powder. We have described the making of starch. A Baking Powder Factory is the simple organization of an establishment for the economical and rapid mixing and boxing of tartar, soda and starch. Pipes lead from bins, and trucks pass under the pipes and take from each of the three

REAPING WHEAT WITH SMALL KNIVES IN CENTRAL INDIA.



HARVEST SCENE IN SOUTHEASTERN RUSSIA.

exactly the quantity that is needed. It is mixed in a machine and put in round tin boxes of various sizes by girls.

How are these powders adulterated?

With alum and ammonia. Ohio, Minnesota and other States were prompt in legislative attempts to make this impracticable, and Germany has passed stringent laws. It is said that if you put baking powder that contains ammonia into boiling water, say a teaspoonful of the suspected powder to a cupful of water, the odor of ammonia can be detected. To find alum, put two teaspoonfuls of baking powder into a glass of cold water. If there be no alum present, the water will effervesce, but alum will prevent the foaming.

What is Graham Bread?

Sylvester Graham was a minister of Massachusetts who died at Northampton, in 1851. At that time Ohio was the Far West. He became a fanatical vegetarian, and attributed intemperance to the eating of meat. Among his other reforms was the idea that bread ought to be baked from wheat flour that had not been sifted, so as to get more of the bran, or at least nearer to the husk, where the gluten lies thickest in the kernel. The millers found a ready sale for unbolted (unsifted) flour, and Graham flour is still a commercial article in the markets of America, though unknown by name in Europe. Of course, dyspeptic people enlarged on Graham's idea, and Boston Brown Bread—a loaf that looks like an English plum pudding—is still served at leading hotels and restaurants. The brown crust of all "bottom" loaves of white bread serves a better purpose in the stomachs of people of delicate organisms, and the judgment of mankind has gone against coarse food as essential to health.

Does climate affect food-practices?

It probably governs them. Man is the only animal that lives on all parts of the earth, for the reason possibly, that he is able to adjust his diet to the necessities of the situation. In hot latitudes, meats and stimulants are denied; in cold regions the same things are suggested. It is found that most of the great religions flourish best in the climates where they originated. Thus it

would be difficult for a devout Scotch Presbyterian and a devout Mussulman to change places and adhere to all their previous ideas. The two hundred and fifty million inhabitants of Hindostan are probably the most temperate people on earth, but the reason is to be found in the hot weather that is their portion in life.

Are Beans eaten?

Yes. The Boston Baked Beans, as they are often called in this country, are first boiled, and then should be "fired" in an earthen bowl and in a baker's oven, with a small piece of fat pork to give them a certain flavor. Thus, the dish forms a kind of pie, with brown crust, much desired by bean-eaters. In New England towns the people took their own bowls of boiled beans to the baker's oven early in the morning. The Mexican *frijoles*, which, with corn, are the main food of the peons, are beans. The common white bean, which is thus used, is noted for its life-sustaining qualities, but is to be easily digested only by very active or healthy people. There are many other kinds of beans, but they are served in America as side dishes and used for pickles. The "locusts" that St. John ate in the wilderness are usually said to have been beans. *Pulse* may be peas or beans, or any podded seeds.

What of new uses for the various grains?

The late war experiences developed a tremendous demand for smokeless powder. All the nations are equipping themselves with supplies of this recent invention. The exact formula of manufacture is a government secret, but immense quantities of alcohol derived from grain are used in the process. Then also, the use of grains for food is increasing faster than the increase of population. Vast mercantile interests have lately been built up on newly invented processes of preparing edible grains as breakfast foods. The consumption of wheat will be enormously increased (see page 415) by the new process of making rubber. The future of America as the great agricultural nation of the world is indeed very bright.

Butter, Cheese, Etc.

What is Butter?

It is the fat of cows' or other animals' milk. It is highly palatable, nutritious, inimitable, and in the form which is common in the Northern States of America, is not known, or is little known, in the older countries of the earth bordering on the Mediterranean and Red Seas and Persian Gulf. It is highly recommended to all persons of spare build or afflicted with lung ailments.

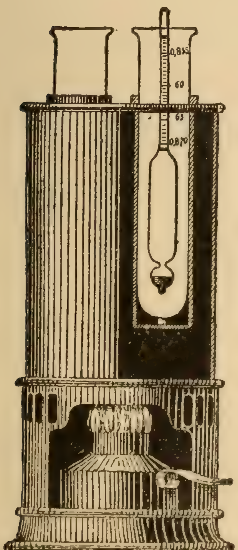


Fig. 56. KOENIG'S APPARATUS FOR DISTINGUISHING MARGARINE FROM BUTTER.

What remarkable things have happened in the butter trade?

The methods of making have been reformed and improved, and the business of adulterating and trying to imitate it has assumed enormous importance. When that great encyclopedia called the History of Adulteration shall come to be written, the principal chapter should be devoted to the war made on good butter by meat-packers and renderers. One by one the good restaurants of the great cities have surrendered to the enemy, until it is only at high-priced and celebrated places that the wayfarer can procure what he pays for—cow's butter. In small households, thanks to the Federal laws, there is far more protection, because the small grocer cannot afford to take out an oleomargarine license for selling substitute butter.

Fig. 57. CHEESE GROTTO AT BERTRICK, BADEN.

What great change in Butter-making has come?

The Creamery, where real butter is made by machinery, and the odors of the old-time spring-house and milk-pans, so readily absorbed by butter, are precluded. As personal odors also entered into the old-time problem of butter-ladling, the modern creamery butter, all the year round, is often as good as the best hand-made butter used to be when grass was at its best.

Where has butter-making led other industries in America?

In Dutchess and Herkimer Counties, New York, and at Elgin, Illinois. The Elgin Creameries became famous thirty years ago, and their practices have been copied in all the grazing regions of the land. At the World's Fair of 1893, a separate building was erected for the dairies.

Describe a modern small country Creamery.

The institution is usually located at a thriving market-town, and is so placed as to be equally convenient to two main country roads. It may have been promoted by men who had machinery to sell, and can be carried with a capital of from $2,000 to $5,000, paying liberally on the investment. A large platform stands about wagon-high in front, and on this platform are the

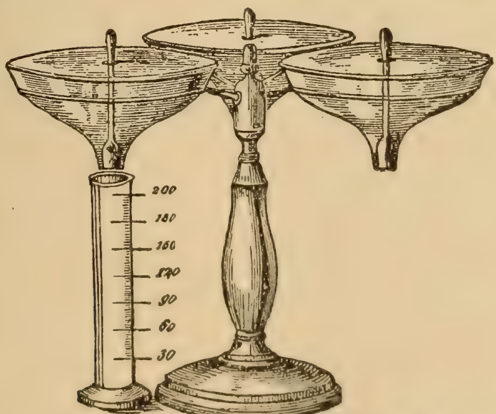


Fig. 58. KROCKER'S CREAM MEASURER.

receiving tank-scales. The farmers drive up with their large milk-cans and the receiving-clerk empties the load, weighs it,

and enters the amount in his scratch-book. After this account has been made, the milk leaves the scales and flows into the big receiving-vat, which will contain three tons of the liquid. Near the big vat is a tempering caldron, with inside steam-pipes, which warm the milk to not less than 59 nor more than 61 degrees. Here it goes into the separator.

Describe the Cream Separator.

This centrifrugal machine has made it unnecessary to "set" milk, and milk-pans are out of use. It was invented in Sweden, where the steel of which the earliest bowls were made was of the highest quality. Later, Americans discovered a method of using sectional pieces of wrought iron piping, and now the cream separator has become comparatively cheap, and there are several great manufactories at Chicago, turning out thousands of machines each year. When a pan of milk is set, it is the force of gravity that is put at work, and the fats rise because they are lightest. If the milk-pail were swung about with great speed, in order to develop and maintain the centifrugal force or momentum, the cream would come toward the hand that swung the pail. If we put the milk in this bowl and set the bowl whirling at a greet speed, the separation will take place almost instantly. Thus a pipe of milk may be leading into the bowl, and two pipes out, for the cream will issue from a pipe at the top and the skim milk from a larger pipe at the side. This machine is geared to run by hand, horse-power or steam, but at the Creamery, the steam engine by which the milk is tempered also operates the separator.

What becomes of the cream?

The little cream pipe leads to a cream vat holding four hundred gallons, or two and one-half tons, while the skim milk goes in a small pipe to the milk vat. At the end of twenty-four hours a large cubical revolving box churn is nearly filled with cream. It is closed tightly and steam-power is applied to the axle on which the box hangs. The machine revolves swiftly, and in less than half an hour three hundred pounds of butter have been formed in the churn. This is thrown on a table and worked or ladled with a heavy lever that is fastened at one end to the table. It is then

salted, packed in large pails, and a salted cloth is spread over it, the cover is laid on, and it is ready for the market street of a great city, or the country store. In the cities, the small grocer goes to the market street early in the morning in his own wagon. In 1881 the price of the best Elgin creamery butter rose to sixty-five cents a pound at the city groceries. For thirty years creamery butter has held the best place in the market, displacing the finest hand-made country butter. An ordinary country creamery will use 1,500,000 gallons of milk in a year, out of which it will make 55,000 pounds of butter and 66,000 pounds of cheese. The average creamery price of butter is ordinarily about twenty-one cents a pound.

How are the farmers paid for their milk?

By the hundredweight—something like 70 cents for standard milk. The commonest adulterations are water,starch and yellow colors, such as the yolks of eggs, carrots and even metallic yellows. To keep milk from showing its age, boric and salicylic acids, soda, and other chemicals are added. Methods have been adopted which discover all these practices. To find the water a gravity tube is sunk in the milk. If a vessel holding a thousand pounds of water be filled with good milk it must weigh from one thousand and twenty-eight to one thousand and thirty-five pounds—both water and milk at 60 degrees of temperature. Suppose we weighted a closed glass tube with iron or mercury and let it stand upright in the water. Now mark the water line 1,000. Sink the same tube in ordinary milk, and the tube will not go down to the water mark. Mark the milk-line, say 1031, and grade the space between the two lines into thirty-one equal parts. This tube would then be a lactometer. If the milk

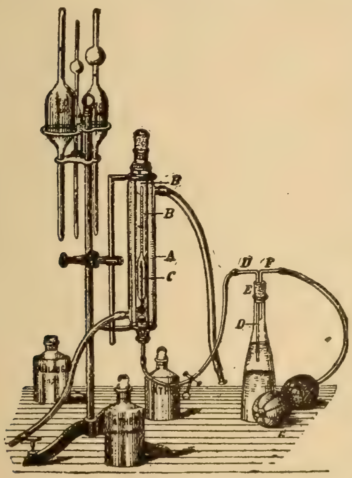


Fig. 59. SOXHLET'S APPARATUS FOR DETERMINING FAT IN MILK.

shows less than 1028, it is certainly watered. If it goes over 1035, cream or another heavy body from outside sources has been added. About 87.5 per cent. of good milk is water. To find starch, tincture of iodine is introduced, which colors the starch cells blue. If there is dextrine in the milk, it will turn red. If the milk-tester discovers a can of milk that does not hold up to the lactometer properly, he can then proceed further.

What is Professor Babcock's sulphuric acid centrifugal machine?

This is in reality a cream separator into which sulphuric acid has been put along with the milk to be tested. What is desired is to know the proportion of fat to the milk. Milk, besides its 87.5 per cent. water, is composed of fat, sugar, caseine (that is *cheese-ine*) and salts. The sulphuric acid destroys the sugar, caseine and salts—that is, reduces them to the condition of water, so that, in the whirling of the test tube, they will stay with the water. The acid lets the fat alone. Now suppose the test tube or bottle to be so finely graded at the nozzle (like a druggist's graduate, or glass scale) that while the milk in the bottle represents one hundred pounds of milk, each mark on the nozzle represents one pound of butter fat. The bottle fits in a tin pail, and the pail is hung on a wheel that stands like the wheel of a car-brake. Then this wheel is whirled by a crank and gearing. Of course many bottles may be hung on at once. As in the cream-separator, the watery parts of the milk are thrown to the bottom of the bottle as it flies out to a horizontal position, and the oil rises to the slim nozzle, where the graded marks show what proportion in pounds it will bear to one hundred pounds of the milk. Each week a test is made which shows the butter-producing quality of each farmer's milk. and he is paid for each hundred weight according to its value as a butter-producer.

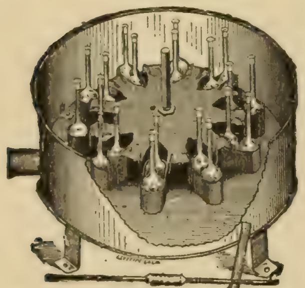
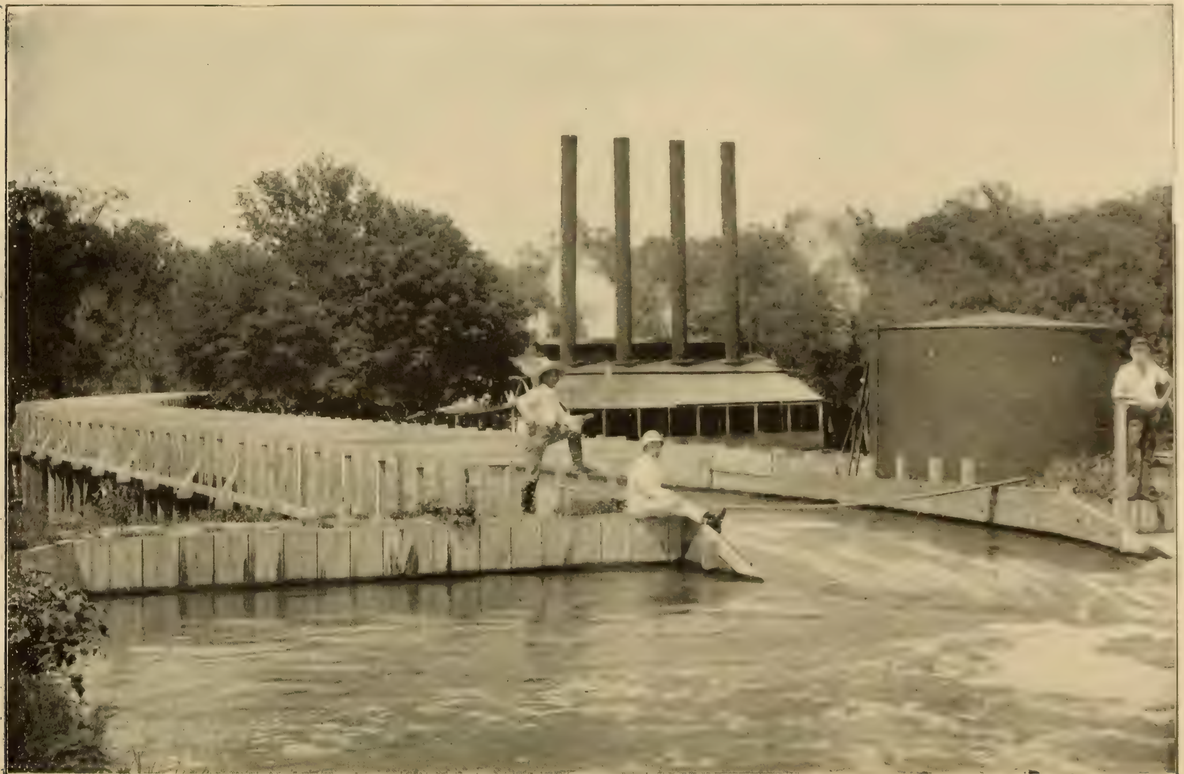


Fig. 60. BABCOCK'S MILK TESTING APPARATUS.



MODERN METHODS OF FLOODING A RICE FIELD—PAGE 119.

What is the history of Butter?

The word *butter* is very old, but the method of making it has varied. The word comes from the Greek *Bous*, ox, cow, and *turos*, cheese—that is, cow-cheese. The Hebrews and Semites generally used the word *chameah*. It was usually a liquid, as Judges 4:19 and 5:25. Yet butter was churned, as at Proverbs 30:33. The Romans preserved the name of butter in *butyrum*. In India ghee is used, which is boiled butter. Beckman (History of Inventions) believes that butter came into Europe by the north, through the Scythians and Goths, and that the Romans used it as a medicine. In Italy, Spain and Portugal, and in the Southern States, oil often supplies the place of butter.

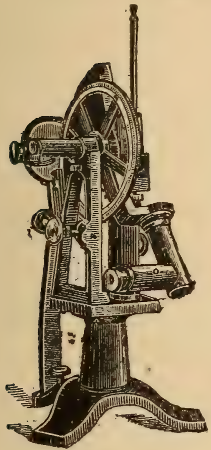


Fig.61. AMAGAT-JEAN'S OLEO-REFRACTROSCOPE FOR TESTING OILS AND BUTTER.

What becomes of the skim milk?

We left that in the big vat. The butter fat had been whirled out of it, but there still remained the caseine. In Latin, *caseus* is the word for *cheese*. Rich cheeses are never made from skim milk, but skim milk cheese is rich in nitrogenous or meaty qualities, and takes the place of animal food. When you set a pan of milk away and forget it, it curdles, or thickens, and turns sour. Cheese is itself a curd. Many acid substances will help to thicken milk, but one alone seems better than all others. It is the fourth or digesting stomach or rennet of a suckling calf. It is cut in strips, salted and smoked. When put in the milk vat it excites a rapid fermenting action, which can be secured by no other means as well, and which is scientifically known as yet only by its effects. To aid the fermentation, steam pipes raise the temperature of the mass, and the whey, or water, or serum, is allowed to escape. The mass is colored to supply the hue of the butter that has been taken from it by the cream separator, and paddled and mixed a good deal, until it is a solid rather than a fluid. It is then poured or shoveled into the

cheese-grinder, which mixes, beats and sifts the substance.

What is it now?

The raw material of a cheese. This is put into hoop steels, the size of the box into which the cheese is to go, and pressure is applied. The hoop is lined with the cheese cloth which is to cover the product. More whey comes out under pressure. The finished cheese then goes to the curing room where it is shelved. A cream cheese ought to stay there six weeks. The skim milk cheeses made at our country creameries bring two cents a pound less than the cream cheeses. Canada excels as a cheese-producing region, and at the World's Fair of 1893, in the Canadian pavilion of the Agricultural Building, the cheese that took the prize weighed 22,000 pounds. In Missouri, an eminent farmer received the soubriquet of "Big Cheese Robbins" for a similar feat of cheese-making.

What foreign cheeses are liked in America?

The finest is Roquefort, which is made from ewes' milk, and is mixed with bread. By curing the cheese in a cave, which holds one temperature the year round, the bread molds in such way as to give a characteristic flavor to the cheese. A taste for this cheese once acquired, cannot be satisfied with any other make. It is the usual finishing touch at great banquets. Roquefort comes in sectional parts of small cheeses, wrapped in tin foil. It is not successfully imitated in America.

What is Edam cheese?

It is usually the red sphere you see in the grocery. It used to be called Dutch cheese. It is colored with *annatto*, *annotto*, or *arnotto*, variously spelled, a red dyestuff obtained from a tree called Bixa in the West Indies. The curd is saturated in salt brine before it is pressed into the sphere, and this gives it the quality of "keeping" in nearly all climates. Probably the celebrity of Edam cheese comes rather from its being obtainable everywhere than from its just place among fine cheeses. All the way through its making, the idea is to salt it, and this was needed to meet the demands of the Dutch trade with the hot countries.

What is Schweizerkase?

This is the great Swiss cheese, which is so highly prized by all the German race in America. It is a very hard goats' milk cheese in which gas has left large bubbles. It is the stand-by of the beer saloon, and is a really fine cheese that cannot be successfully imitated in America. The American substitutes lack in color, gaseous effects and taste. The smell, like that of all goats'-milk cheeses, is offensive to American nostrils, and Schweizerkase (that is, Swiss Cheese) is vulgarly called Limburger on this account, but we rarely see the latter. Limburger is sold in tin foil.

What are De Brie and Camembert?

They are fine, rank-smelling French cheeses that come in small packages, and are pasty in substance. They are eaten by epicures both to satisfy an acquired taste, and to promote digestion, for it is usually said of these cheeses that although they are themselves indigestible, they may be eaten to digest other food.

What is Parmesan cheese?

It is a cheese made on the banks of the Po River in Italy. It comes to America in bottles, the cheese having been rasped into crumbs. It is popular as a dressing for macaroni. But a great deal of this cheese becomes rancid from age, and judgment is required in buying. As a general thing, the foreign dainty that is seldom called for, being disliked by the masses of the people any way, is in bad condition when it is bought, and probably the Edam cheese is the only product of the kind that is fairly proof against the tooth of time.

What is Schmierkase?

Smear cheese, that is, whey cheese. It is made by housewives all over the world. One of the fine cheeses—Neufchatel—belongs in appearance to this class of white, simple, unground, unleavened, unpressed, uncured curds. Yet the Neufchatel, although it looks as though it had been simply prepared, has been very carefully pressed out of sweet milk, with rennet.

For what are English cheeses noted?

For their high flavor, color, purity and keeping qualities. The best are called Stilton, Cheddar, Cheshire, Wiltshire, Gloucester, etc. Stilton is made in Leicestershire, but is called

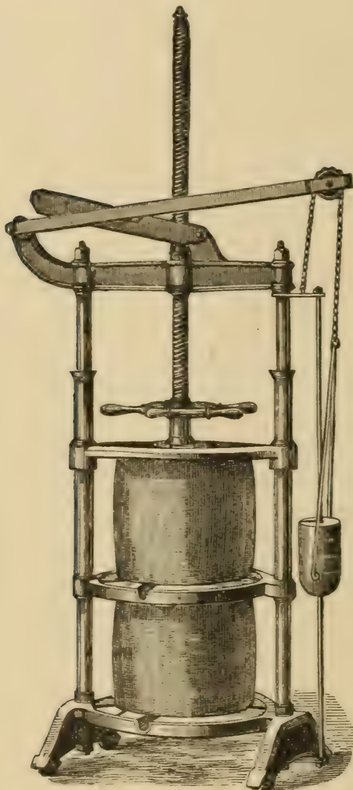


Fig. 62. A CHESHIRE CHEESE PRESS.

after a town in Huntingtonshire. The cream of an evening's milking is added to a morning's new milk, with rennet. The curd is not broken or paddled, but drains itself in a sieve gradually, and afterward under gentle pressure. Green mould comes on it when it is ripe, and care is exercised in all stages, even to eating it. Its fame in the English-speaking world is

very great. The American cheeses were for many years very poor imitations of England's output, and are yet considered tame and inedible by many epicures, but it must be considered that epicures eat cheese as a dessert, while the American farmer, laborer and business man often depends on cheese and crackers for a good lunch.

What animals give milk that is made into cheese, butter, or liquor?

The cow. In mountainous countries, the goat (Neufchatel and Swiss cheeses). At Roquefort, the sheep (Roquefort cheese). In Lapland the reindeer. In Russia, the mare, where Kumyss is made. In the Arabic deserts and countries, the camel. The cream is put in a skin sack and the sack is swung until the butter comes. Asses' milk is highly esteemed as a food for invalids in northern lands.

Has imitation flourished, as in the case of butter?

No. There is nothing to imitate save the fancy foreign cheeses, and there the epicure is an efficient judge for himself. But American cheese-makers have been abroad to study all the methods, and when the importations of a fancy cheese become notable—(the entire amount is not large)—that cheese is put on the market. One factory in New York is said to produce two hundred thousand foreign cheeses. They deceive nobody who really likes foreign cheese, but in the way of Schweizerkase the American bogus product displaces a really good article to a considerable extent. And here, where success is the greatest, the imitation is the poorest.

What is Club-House Cheese?

A home product for which Americans deserve credit. It is full cream cheese, run through a grinder, mixed with butter, salted, cured also with a little brandy, put up in a glass, covered with paraffin paper, and a glass top screwed on. Here we have a package that will keep and will not absorb odors, or, what is better, give them out. It is also of a size convenient for purchase and use.

What is the principal imitation of butter?

Oleomargarine, generally called butterine. A Parisian chemist

named Mege Mouries is credited with establishing the first imitation dairy in the world in 1870, during the siege of his city. The instant success of this institution led to the establishment of similar factories at the Stock Yards in Chicago, and it was not long before the farmers of America were confronted with a rivalry that was harmful in many ways. The new product undersold and cheapened butter, and yet was sold as butter. People who had paid for one kind of food got another. But first of the thing itself—oleomargarine or butterine. If olein were the chief element of butter, could not olein be rendered from other parts of a cow than her udder? Margarine, like Margaret comes from the ancient name of the pearl. It was a pearl-like fat. The word had long been in our large dictionaries. Olein is a modern word, but oleic acid can come from any vegetable or animal oil. The compound word Oleomargarine was brought into the world by the Parisians, and excited the greatest scorn in America, where the substance was to win its chief triumphs. The caul-fat of the cow, covering the intestines, was found to contain olein to the extent of twenty-nine pounds to each animal, and this caul-fat or olein, or oleomargarine, or tallow, as it may properly be called, is expressed in oil, and shipped to Holland, to the extent of $10,000,000 worth a year. The Hollanders pay nearly ten cents a pound for the oil.

Describe a butterine factory?

It may occupy a large building near a slaughter-house. The intestinal tallow or caul-fat is dumped in a tank of water, where the blood and dirt are washed away. The fat next goes to rows of iron cauldrons lined with steam pipes and the temperature is raised to one hundred and fifty-five degrees, for the fat must not be burned. Revolving arms stir the fat, and it slowly tries out. It drains into large clarifiers, where a sediment that is not wanted settles to the bottom. A siphon draws away the clear oil into tin-lined trucks, which are trundled to a so-called cool-room, where the temperature is maintained at eighty-five degrees. Here it cools and granulates.

What is next?

It now goes to the press-room. The tallow in the truck has

a yellowish cast, upholding the chemists' claim that it contains the principle of butter. Men now prepare it in little cakes for the presser. In front of each man is a small square mould. Over the mould a piece of white duck cloth is spread. The mould is then filled with tallow and the duck is folded over the square cake. Eight cakes are then placed on a piece of sheet-iron under the big press, and covered with another piece of sheet-iron. Eight more cakes are put on, and thus the stack is built up until there are sixty layers and four hundred and eighty cakes. Screw pressure is applied, and the oleomargarine oil is expressed from the cakes.

What remains?

Stearine in flattened cakes, pure white and almost tasteless. It is used as an ingredient in making certain brands of lard. The oil that comes away from the press was of a bright amber color. It again goes into steam-pipe cauldrons, where it is stirred by machinery. The temperature is raised to one hundred and eighty-five degrees, and it is again run into tin-lined truck-tanks and chilled. Now the oleomargarine passes through a bath or brine, and then granulates, resembling a light brown grade of sugar, and slightly resembling butter in taste. It is packed in tin-lined trays, six feet long by three feet wide, and goes to the store-room.

What is Neutral?

It is leaf lard, from swine, that has gone through the brine, and is now to be used as an adulterant of this adulteration, for you see the manufacturers are not able to make enough money out of pure oleomargarine. The trays of Neutral are placed in the same storage with the oleomargarine. A chute leads from the storage floor to the creamery, and workmen, as the trucks holding oleomargarine and Neutral are trundled out, shovel them in equal parts. Forty per cent. of the butterine we eat is lard. Forty per cent. is oleomargarine.

What is the remainder of 20 per cent?

In the best butterine it is good butter. The chute leads to a vat, where the two kinds of fat are heated to one hundred and eighty degrees, and stirred by men with paddles. We are now

in the churn-room. Near by are all the appurtenances of the genuine creamery which we have previously described—milk-vats, cream separator and revolving butter churn. As the butter is churned, it is added with some of its buttermilk, to the big vat, where the men still stir with paddles, and perform what they call the operation of churning. If color be needed, it is added, exactly as at a country creamery, the same pigments being used.

Is the mass worked?

Yes. It goes on a circular table, and a long conical roller or butter-worker squeezes out the buttermilk and mixes in the salt which the operator adds, using meanwhile a wooden paddle. Again it is loaded into tin-lined trucks, and stands a day, when it once more goes on the circular table. Now it is ready for the packing-room down stairs. Here the United States takes a hand. Each package must be marked "Oleomargarine" in plain type, and the factory number must be added. The maker must pay a license tax of $600 a year, and a wholesale tax of $480, with a tax of two cents a pound on all the product manufactured. Retailers pay $48 more, yearly.

Are there any State regulations?

Yes. In some of the Pacific States the keepers of inns and boarding-houses must place before each guest a card bearing a definite notification that the stuff set before him is sham butter, and the chemical ingredients must be separately stated.

Is there any other adulteration?

Yes. Cocoa is used. In 1895, there was established at Chicago, a factory for the manufacture of butter and lard for household use from cocoa-nut oil. Ceylon produces cocoa-nuts in enormous quantities, and the oil or "butter" is shipped to America at the rate of twenty-five million pounds a year, for the use of soap and candle-makers. But an inventor named Campbell found a new use for it.

Describe a cocoa-butter factory and its output?

The pipes or barrels of cocoa-butter are carried to the top floor, which is heated to one hundred and thirty degrees. The

butter in the barrels turns into oil. It is then poured into cauldrons which are jacketed with hot water, like oatmeal cookers. Into the cauldrons, mixing with the oil, the inventor puts a secret solution, which kills the fermenting germs of the oil. The oil next goes down-stairs and is mixed with water. The secret solution unites with the water and leaves oil. Then a centrifugal machine or cream-separator, making four thousand revolutions a minute, throws away the water and the solution. It is now "stock," ready for use.

What is done with it?

If it goes into immediate use, it is poured on top of water in tin vats. Into the water a cold air blast is injected with great force, and this churns the oil into granulated white butter. It goes to a store-room, where it "ripens," somewhat like cheese, developing acids that are desired. It may now be mixed with creamery butter, exactly as at the butterine factory. The capacity of this factory is twenty thousand pounds daily. Without mixing, the product becomes a substitute for lard, and its makers claim for it many advantages over the fat of swine for cooking purposes.

What is Condensed Milk?

It is milk from which three-quarters of the water has been evaporated. It was put on the market three years before the Civil War by Gail Borden, who erected a factory at Wolcott, Conn. A few years later an establishment was started at Elgin, Ill., where the milk of 2,000 cows is shipped in tin cans to all parts of the world, and several factories are operated by the New York Condensed Milk Company. The milk comes to the factory as it does to a creamery, but perhaps even more care is taken as to cleanliness, and to prevent souring. At the scales the milk undergoes an eye and nose inspection, and all suspicious deliveries are sampled for the chemist's tests. Before the farmers' cans are returned, they are scalded, and they must be washed again at home. The copper storage tanks hold twenty thousand gallons. Thence the milk goes to "wells" where it is heated to the boiling point, and is strained off into the sugar-

mixer, where granulated sugar, the preservative, is added. The mixture of milk and sugar is now ready for the vacuum-pans, for it is to be treated exactly as sap or sugar-cane juice are, "boiled down." But it requies a temperature of only one hundred and forty degrees, and the evaporation is rapid. The remainder is condensed milk, a thick, white or cream colored custard. It goes to the coolers and thence to the little cans.

What is its use?

It goes with the explorer across the forests of Africa, and with the civil engineer when he traverses Siberia or bridges the Andes. It is carried with every sportsman's outfit into the deep woods ot America. Its reputation is so high that the factory keeps up a system of outside inspection, whereby every cow that contributes to the supplies of the factory is examined as to the condition of her health, and only certain kinds of food are allowed. The tin cans are made at the factory.

To what other use is condensed milk put?

It is evaporated without sugar and sold in large quantities to the manufacturers of ice cream in cities, and to bakers and confectioners who use it in place of cream.

What is pasteurized milk?

Milk raised to a temperature of one hundred and sixty-seven degrees Fahrenheit, and kept at that heat for twenty miuutes. In this way all bacilli are destroyed. A double boiler is used—that is, the outer vat is set in surrounding water. Large quantities of milk are thus prepared at factories for use in the market as food for infants and children.

What is Kumyss?

Kumyss or Koumiss is an effervescent drink prepared from mare's milk by the Tartars, Calmucks etc., and imitated in America by manufacturers who make it from cow's milk. The Russian method is as follows: The fresh mare's milk, noted for its sweetness, is diluted with one-third to one-sixth water, and placed in a sack of goat-skin, or a bottle made from the

skin of the entire hind-quarter of a horse. The yeast used is *kor*, the sediment from a previous brewing. The bottle must be frequently shaken. In twenty-four hours the fermentation is complete, and the young "Kumyss" is made. It is called *saumal.* Fresh milk is added daily and water evaporates from the surface of the hide. The Russian beverage is highly intoxicating, but the American Kumyss will not make anybody drunk. About 1876, it was well advertised in the European cities as a health drink, and invalids in America very generally tried it. Many persons who do not like butter-milk enjoy the taste of Kumyss as it is made here.

Fig. 68. GATHERING DATES.

Fruit.

Is America well supplied with Fruit?

Yes. On account of the facilities of modern transportation, the people enjoy the luxuries of all climates. The golden figs of the precincts of Jerusalem, the bananas that pile the wharves of New Orleans and other sea ports, the citrus fruit that the Pacific coast has so gorgeously displayed at all our world's fairs —and at all of Europe's—these appetizing and tempting foods are now for everybody. Commerce and the guardians of the public health unite in urging fruit on the favorable attention of mankind.

What do you consider the most important American fruit?

The Apple. Its tree is hardy, and has been known to live two hundred years, although an orchard usually dies or ceases to bear in fifty years. The wild crab apple of the old world, is thought to be the parent of all our apples. The varieties best known are perhaps the Rhode Island Greening, Bellflower, Pippin, Northern Spy, Rambo, Russet, Spitzenberg, Nonesuch, Wine apple, Baldwin, Snow apple and Seek-no-further. The Rambo is good at harvest-time. Such apples as the Greening and Northern Spy are hard and sour at that season, but in the middle of winter they soften and granulate, becoming delightfully edible at a time of great need. The Russet, thick-skinned and forbidding to the latest moment, is the last to be eaten, and serves as the final reminder of the previous year. We export many apples to Europe. New York is a celebrated apple region because its orchards are well established.

What followed the failure of vines in France?

The culture of apples, and the use by the French of cider as a drink, until a billion gallons a year were consumed.

How are Apple trees improved?

By grafting. The old Indian orchards, so frequently met in the West, show a fruit not much above the crab-apple in quality. A branch is sawed off, and the twigs of a good apple tree are inserted in the split end of the amputated trunk. The graft is gummed in, and the new branch that grows bears better apples. The twig is called the scion, and the branch the stock. There are various other forms of making the juction, but the split is commonest. Webster's Dictionary gives a good and full illustrated account at the word "Grafting."

How are Apples consumed?

They are barreled and stored in cellars for consumption at the fireside. They are dried and sold at the groceries. They are made into a preserve called apple-butter. They are crushed for their juice, which ferments into cider, and this cider is boiled into a thick sirup. They are sliced and canned for pies, and apple pie is eaten everywhere.

What is the Alden process of drying?

A wooden chamber is built. Through this chamber endless chains operate by stages, moving once in four or five minutes. On these chains are placed trays of the apples or other fruit to be dried. Below the chamber a steam coil heats a blast of air. The air comes from a blower driven by a steam engine that heats the coil. The air grows less humid as the chain descends through the chamber. If necessary, moisture is imparted to the air blast. The process was called Supermaturation by its inventor, who likened its action to the course of nature in the Bartlett pear and the fig after they are plucked from the tree.

What fruit closely allied to the Apple has become common?

The California or Bartlett Pear. On account of the opening of the Pacific Railroad, in 1869, the further cheapening of transportation by rival lines, and the capability of this fruit to self-ripen on its long journey, the yellow pear, during its season,

in the autumn, is the most notable fruit on the stands of the street-vendors. So novel and delicious was this fruit regarded in the States east of the Mississippi in 1870, that single pears sold for from fifteen to twenty-five cents each on the streets of the cities. At that time there were about two hundred and eighty thousand pear trees in California. The number enormously increased, and it was found that it would be profitable to ship even the smallest specimens of the fruit eastward. The native pears of the Eastern United States have a thicker green skin, and never take on a golden yellow. But they are preferred by many. Pears are canned more largely than apples. The cider made from pears is called Perry. The pear is as old historically as the apple, and both were well known to the ancients.

What can you tell me of the Peach?

It is an ancient fruit, being the *Tao* of Confucius, 500 B. C. The Nectarine is an outgrowth of the Peach, and the Peach is probably an outgrowth of the Almond. The Plum is very closely allied to the Peach. The Peach comes to Western civilization from Persia, and belongs to the botanical genus *Prunus Persica* According to the soil and climate in which it grows, it varies from a small, mealy, indifferent ball of vegetable fur, to a very large, rich, juicy, highly flavored aad beautifully colored article of diet and refreshment. The Peach grows best at the margin of great bodies of fresh water, from which steady winds blow, as on the eastern coast of Lake Michigan, where a poor sandy soil has furnished some of the best Peaches in the world. The Peaches of California are still larger.

Are there two kinds of all Peaches?

Yes, clingstone and free stone. The clingstone Peach, while considered of superior flavor, does not cut up so well, but serves as conveniently in preserves or sauces. It comes very early.

How are Peaches cultivated?

They are planted in orchards, and several of the battle-fields of the civil war were fought over Peach orchards, as at Shiloh and Gettysburg. As the tree is somewhat like a willow, its thick foliage offers shelter from view, without safety from bullets, so the Peach orchards of battle have been death-traps,

where the carnage was always worst. A disease called "yellows" attacks the trees, and entire regions are denuded of their orchards, but it sometimes happens that individual trees resist disease with the good fortune of individual men, and for no better known reason. The Peaches are shipped from the orchards in baskets holding a bushel or one-fifth bushel. The small circular baskets have passed out of use. The common form is long and low, with a handle. The supplies for a great city make shiploads daily, and fruit trains also run on the railroads in season. Over two million baskets come to a city like Chicago in a year.

How are Peaches used?

They are sold on the streets, to be eaten in hand. They are eaten raw on the table, sliced, with sugar and cream, and are nearly as highly esteemed in this way as strawberries, but are extremely perishable, requiring greater care in serving. They are stewed. They are dried, like apples, and this was once the common way of preserving them. They are made into Peach butter or jam, a thick sauce, and the fruit makes an excellent pickle, cloves being thrust in the sides for flavor. The Peach pie, made all the year round, is as staple as the apple pie at the city restaurants and lunch counters, and the consumption is enormous.

Are Peaches canned?

Vast quantities are prepared for use by canning, and doubtless the canned Peach, as you see it at your grocery, leads all other forms of commerce in preserved fruits. There are great factories where the round three pound tin cans are made; there are great printing-works, where the most luscious peaches are pictured on paper, for the outside of cans, and at nearly every town where Peaches are raised for the market, the canning establishment flourishes. At first the fruit was peeled and stewed in a heavy liquor of sugar and water, but subsequently it was learned that the public preferred a cheaper and thinner preparation. The skin of a Peach is best removed by scalding. The general operation of canning is described later. (See Tomato.) The Peach is always sliced into halves, and the pit is taken out. The canning factories, by operating near the

orchards, furnish needed employment to the boys and girls of the town.

Do the California Canned fruits rank separately?

Yes, and in three grades or qualities. The names of the Peaches usually chosen for canning in California, are Lemon Cling, White Heath and Yellow. Attempts are also made by the trade to supply Peaches in cans for use on the table with cream.

What is the Apricot?

It is a Peach with a smooth skin. It does not grow so large as a Peach, nor does it acquire a flavor so fine. It comes on the markets of America for short seasons, but cannot compete with the Peach.

What is the Nectarine?

It is still another small smooth-rind Peach that comes from Persia along with the others. It is a California fruit and does not figure on the Eastern markets.

The Cherry is also an important fruit, I think.

Yes. And both kinds, the Eastern and Western, have their admirers. The Cherry of the East is red, juicy and luscious. The Cherry of California is much larger, but has less flavor. It is somewhat sweeter, with less of the cherry acid, which is so highly liked by many. Both kinds of Cherries have their origin in Asia, and it is said that Lucullus brought them to Rome when he returned from his campaign. The California kinds are called Ox-heart, both red and white, but they are also known as Dukes and Bigarreaux. The Eastern or common red cherries are called Morello and Gean (from Guigne). The householder finds that they play an important part as a canned fruit, and beside the immense quantities put up by Eastern women, the sale of California canned Ox-hearts is very general. These are called White and Black. The California Black (Red) Cherries that appear for a while on the fruit stands of America, are, for such purposes, perhaps the finest fruit we see. Our own Eastern cherry orchards are famous, and no tree could be more beautiful than a Cherry in May, when it is in full bloom, or in July when

it is loaded with its gleaming red berries. Cherries are never cheap in the great cities. The hucksters cannot sell them on account of high price, and the season is short. There are about one hundred varieties.

What is the Strawberry?

It is considered by mankind generally to be the most desirable product of the earth, and a taste for Strawberries usually endures far into middle life, or perhaps to death. The Strawberry furnishes one of the greatest commercial interests we have, and doubtless there are few Americans who do not each year obtain as many berries to eat as they ought to get. Nature gives a short period for the eating of this fruit, but at a city like New York, the season begins for the rich as early as March, and ends as late as August.

Where do the word and the berry come from?

From the earliest races, who called it a stray-berry, a straying plant. The Aryans had the same word as stray for star. The scientists tell us that the strawberry is as if a wild rose had turned inside out, the stalk becoming swollen into a tumorous condition, with the seeds, which are little nuts or fruit, sticking in the side and exposed to the air.

What makes the Strawberry red?

The oxidation of its tender tissues—the same tendency that is in every green thing, as happens to all the autumn leaves. Where redness favors the life of a plant, it grows very bright; elsewhere the tendency is suppressed. Now the Strawberry, with its astonishingly malformed seed-holder, needs the birds to carry it away, for the birds cannot injure its seeds, but must scatter them in the earth. So its tendency to red is heightened. A plant so widely grown, with so many curious men at work upon it, must show the utmost variation, and it may be generally said that this variation has resulted in a poorer berry, and man would have done well to let the birds alone. Some berries are offered on the market that have no more juice than a banana, and less flavor. The wild Strawberries are still the sweetest.

How are Strawberries distributed?

They are carried to cities and towns on fruit trains, which make trips of five hundred miles or more, the strawberry harvest beginning on the Gulf of Mexico, and going slowly northward to Canada, which is reached in July. A quart box with a high bottom is used. Two dozen of these boxes are piled in two layers in a larger box, and the grocer exposes the fruit with the top of the larger box off. Shiploads come to New York and boatloads to Chicago, the Michigan harvest being especially large. Something like a million cases a year pass into or through a large city. The Strawberry cannot be satisfactorily dried, canned or preserved, which perhaps tends to strengthen its hold on the appetites of the people.

How are fruit boxes and berry boxes made?

Blocks of black ash are boiled in a steam-pipe cauldron. The hot logs, three feet long, are put in the lathe, and a knife turns the log into a sheet of veneer. The veneer is sawed into narrow strips for baskets or wider strips for boxes. To make a bushel basket, strips are placed in a ring or mould, so that they will all cross one another at the center of the ring. Then a punch drives a rivet at the center. The wheel of strips is then put on a metallic basket-form, and a ring descends which moulds the wheel down around the form. The lather or basket-maker then nails on strips of veneer for hoops, just as a cooper would do, passing around the apparatus as he nails. This operation makes an acrobat of the expert, as hands, feet and mouth are always busy. A boy puts on the bottom hoop, which is to protect the basket. The handles, carefully made, are put in place by a boy, and a machine sews them on with wire.

How are berry-boxes made?

The variation from the process just described is not important. Two pieces of veneer are crossed. A machine descends and cuts part way through the veneer at the places where it is to fold upward. It is now bent on the box-form and a wide strip of veneer, extending below the bottom, is nailed around the entire box, making a double thickness of wood. The factory gets about half a cent for each box. A man named Halleck is said

to have invented the hollow bottom, making shipment of filled boxes in crates easy and practicable. He patented the idea. Box and basket factories thrive in all the American fruit regions—particularly in Michigan, California, Illinois and New Jersey

What is the Raspberry?

A delicately flavored berry of many colors, growing on a bramble, thorny vine, or bush. The old name was *Raspise Berry* and Bacon calls it a *Rasp.* The name comes from the file called rasp. This fruit appears on the market just as Strawberries are closing out. It comes in pint boxes. The red berries are so fragile that fermentation or mould sets up soon, and they are not easy to distribute. The black or blue berries are dry or seedy. It is in the preserves that the full flavor and beautiful purple of the dark raspberry are obtained,

What are Blackberries?

A fruit similar to the Raspberry. Neither is a berry, but a collection of little cherries, nuts, or peaches called *drupes.* The Blackberry crop is very important, and a wide distribution takes place among the people. Blackberry pies are widely consumed, and the flavor obtained in cooking is nearly as delicate as that of the Raspberry. The people preserve them in glass jars, and the Eastern Blackberry is canned. Some varieties of the fruit are cultivated too far, and the result is a product remarkable for the size of its seeds. Blackberries are held in esteem as an astringent food in dog days, and the Canadian or dew berry is one of the sweetest outgrowths of Mother Earth.

What is the Blueberry or Whortleberry?

It is also called the Huckleberry. The Blueberry grows on tall shrubs in marshes. The Huckleberry is black, round, and grows in dry ground on a very low shrub. Blueberries are sought for harvest pies, and form a notable article of commerce in the Eastern States. They are canned, but are not popular in that form. Blueberries come to the cities in the same way that the other berries are sent, and are sold by the quart. They are used most largely for pies at the bakeries.

What are Grapes?

Grapes are the source of Wines, and therefore are the most important of crops in certain regions. In New Jersey, and along the North Atlantic shore, in those parts along the south shore of Lake Erie and on the islands, and on the Pacific Coast, no other product occupies so much attention. But we here desire to speak of Grapes as a table fruit, or for food. In general, it is with Grapes as with Cherries and Pears—there are two main kinds, California and Eastern. California Grapes are large and "white"; Eastern Grapes are smaller and either blackish-blue or reddish. The California Muscatel Grape is generally distributed in five-pound baskets over the country, and is the richest or sweetest in flavor. California, Ohio, New York, Missouri, Illinois and Pennsylvania are in their order, the principal Grape-growing States, viewed from commercial results.

What are the Isabella, Concord and Catawba?

These are grown from Canada to North Carolina, are favorites in the Kelley Island districts, and are all offspring of *Vitis Labrusca*.

Mention some other kinds.

The Southern Fox, or Muscadine, or Bullace, not found north of Maryland. The Scuppernong and the Mustang of Texas are relatives of this vine; so are the Mish, Thomas and some other Southern Grapes. The Summer Grape has varied into the Delaware, Herbemont, Rulander, etc. The Frost Grape has a fragrant flower and has many names, like Clinton, Taylor, Franklin, etc. There are nine of these families.

What is the California Grape?

It is the *Vitis Vinifera*, or winebearer. It might also be called the raisin-bearer. And the cream of tartar of all our baking powder owes its existence to the same kind of Grape. It may be known as a family, by the fact that the skins cling to the pulp, nor is the pulp so tough as it is in the dark or red Grape. In the dead of winter we get a Grape of this order from Malaga, Spain. It comes in barrels, packed in sawdust, and sells at a high price, Invalids find it cooling and grateful

to the taste, but the Malaga has no such sweetness as the Muscatel.

What are Raisins?

Dried Grapes. They are nearly always "white" Grapes. Sometimes the stem of the cluster of Grapes is cut partly through, and the fruit dries on the vine, and "Raisins of the Sun" are thus secured. The clusters may be gathered, dipped in lye to soften the skin, and spread in the sun. Sometimes, as in Asia Minor, the clusters are dipped in water on which floats a layer of olive oil. The oil gives a lustre to the skin. Spain is the source of the finest cluster Raisins, which are dried from Malaga Grapes. The Raisins and "currants" of the Mediterranean, are small and inferior. California is producing good Raisins, and in time the California Muscatel should be the best, as the Grape is the sweetest and best flavored in its mature state.

How do Grapes grow?

On large trailing vines. In the wild state the vine may reach the top and overspread the tallest tree of the forest, though saplings are usually chosen. Although there are many thousands of vines, the name of Vine usually designates clearly the stock on which Grapes grow, so ancient is the practice of grape-culture, and so important the commercial industry. The vine and figtree represent home in the ancient world.

Name the principal members of the Citrus family.

The Orange, Lemon, Lime, Citron, Bergamot, Cedrat, Lume, Tangerine, Shaddock or Grape Fruit. The oils of all these fruits are isomeric with each other—that is, the same elements are present in apparently the same quantities, yet, in mixing differently, a different chemical product results. They are also isomeric with oil of turpentine and other oils. Grape Fruit has come into wide demand as an aperient and anti-scorbutic food. It is said that a Captain Shaddock introduced this tree in the West Indies.

For what is the Orange remarkable?

For the beauty of its color and shape and the perfume which

it exhales. It grows on a beautiful evergreen tree and its cultivators grow enthusiastic as they produce it for the market. The climate which is required for Orange culture recommends itself to all invalids, and Orange groves have thus united themselves in popular thought with health, joy and peace.

Where are the great Orange groves of America?

In California and Florida and on the Gulf coast. These regions view each other jealously, though it often happens that untoward weather throws one or the other of them out of the market.

Where do our foreign Oranges come from?

Sicily, and other islands of the Mediterranean. Something like 2,000,000 boxes are imported. The Oranges of the Azores are celebrated, but of late years Florida has grown a large Navel Orange that has no superior in size, quality and absence of seed from the pulp. The California Navel Oranges have long been celebrated.

What are Citrus Fairs?

Expositions of all the fruits, like Oranges, Lemons, Limes, Citrons, that are allied. The fruit is built into towers, pyramids, bells, gateways, and the plants are shown in full bearing, or with fruit unpicked and hardening. What was practically a citrus fair was to be seen in the California exhibits at Chicago in 1893, and similiar fairs have been held in all the Eastern cities.

How is the fruit packed?

Each Orange is wrapped in tissue paper, and an oblong box with a partition is packed full or more than full. A thin cover is pressed on, and the box is ready for its long journey in the fruit car. At the market streets of great cities, the grocers and hucksters are supplied, but probably the greatest sale is accomplished at the fruit stands in the streets, where the Orange is the standard attraction, along with the Banana, of which we spoke in our chapter on Bread food.

Name some fancy Oranges.

The Blood Orange comes from Malta, and is grown all along the Mediterranean. The Mandarin Orange is from China. It

was taken to Portugal. Thence the Arabs carried it to Constantinople. Thence it went to Morocco, and the Tangerine Orange results. It is a little Chinese looking fruit, of no special excellence beyond its value as a curiosity.

Give me the history of the Orange?

It originated in Northern India, and the Sanscrit poems call it *Nagrungo.* The Hindustani made this *Narunjee.* The Spaniards made this *Naranja,* and the Arabs *Naranj.* In the Western tongues the *n* fell away. The Italians called it *Arancia.* The Romans had called it the apple of Media, but it was Latinized *Aurantium,* which agreed well with its golden color. The Romance languages made it *Arangi,* and the English *Norange,* clinging to the Persian word. But like other words in English beginning with a consonant, the article *an* stole away the *n*—that is *a Norange* became *an Orange.* (See Townsend's Art of Speech.)

What are Lemons?

They are another form of Citrus, yellower and sourer than the common Orange. In fact they are valued alone on account of the large amount of citric acid which may be squeezed out of them. This is used for the national drink of lemonade, so cooling in the hottest weather. Citric acid is prized as a cure or ameliorant of rheumatism, but lemonade should not be drunk so steadily as to harm the mucous tract of the body, the acid being very strong.

Where do Lemons come from?

Two or three million boxes are imported each year. Their value is $4,000,000 or $5,000,000. Lemons are raised in Florida and California. The trees are tenderer than Orange trees, but the fruit will keep better, and as the supply is always comparatively short, the profit is larger. The tree, too, is one of the most fertile of all growths, bearing as many as three thousand Lemons in one season. It is, like the Orange tree, a beautiful evergreen, with thick regularly formed leaves, but does not grow so symmetrically as the Orange tree. It reaches a height of twelve feet.

A SCENE IN THE STRAWBERRY REGION OF WESTERN MICHIGAN.

Is Lemon a favorite flavor?

It is. Pieces of the peel are put in puddings, pies and liquors. Lemon is served with meats. So necessary is the Lemon to epicures that Sidney Smith made a famous joke, when he was out of London, by dating a letter "Twenty miles away from a Lemon." The flavor is contained in the oil-sacks of the peel. Oil of Lemon and Extracts of Lemon, as sold by the trade, all have something to gain chemically before they will report the true flavor of a simple piece of Lemon peel. It often happens that the turpentine principle rather than the *citrus* principle is secured. At the soda fountains improvements in the art of expressing the oil of Lemon are yearly coming into vogue, and reinstating the flavor in public esteem. The ice cream makers use Lemon scents, and the confectioners put it in their candy.

How are Lemons distributed to the people?

They go in the original boxes to the groceries. There the housekeeper buys them by the dozen. The street hucksters rarely sell them, and then only in closing out stocks, the wagon being filled with Lemons. Saloons must always keep them, and although the sale of lemonade in saloons is not large, the use of the fruit is constant. It is practically imperishable, and deservedly enjoys the highest reputation among the people, high and low.

Is Lemon or Orange Peel sold?

What is known as Fancy Leghorn Orange Peel and the same brand of Lemon Peel come in drums holding twenty-two pounds. They sell at the same price. Fancy Leghorn Citron Peel brings a price one-third higher.

How is Extract of Lemon made?

As we have suggested, the natural essence of Lemon is not wholly soluble in the rectified spirits of wine; but Lemon peel may be "digested" in alcohol until the peel is brittle. The peel may then be powdered. The best flavor obtainable may now be transferred to the alcohol by letting that fluid percolate

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through the powdered peel. This must be carefully kept, or it will become the extract of turpentine.

What is the Lime?

It is practically a small Lemon. It is grown in Lemon countries. The juice is used for many medicinal purposes, and for drinks. Candy tablets strongly impregnated with the sour juice are sold at the drug stores. The English would have done well to have spelled Lemon with an *i*. Then the meaning of *Lime* would be more apparent. Lime juice is preferred to Lemon juice as a preventive of scurvy in the naval service of the world.

What are Tomatoes?

All the English books credit them to South America, but Linnæus has named the fruit *Lycopersicum esculentum*, which would indicate a Persian origin. The Tomato is grown in all North American gardens, although it was once considered a hot-house plant, and even now must be set out with care. The fruit is of many colors and forms, but the large red variety is the one of commerce. The Tomato is sliced and eaten raw with vinegar or oil and it is stewed. It is sliced and forms a leading material in various kinds of pickles. It is the best flavoring for stock sauces and meat gravies.

Describe the canning of Tomatoes.

As this is one of the leading industries in this line, and as the canning of corn, beans, peaches, apples and cherries is done on the same lines, we may profitably note the operation at some length, once for all. A long low building with steam plant is occupied, and many women are employed. The cannery will turn out from thirty thousand to sixty thousand cans a day, ready for the cars. The Tomato is taken from its bin and put in a cylinder which is partly filled with hot water. Through this water a screw shaft revolves, which carries the Tomato slowly along to the end, lifts it out, and sends it over a slide into a pail. This pail, numbered, say 14, goes on a movable or traveling table to girl No. 14, who pulls it over to the stationary part of her table. The tomatoes can be denuded by a quick motion of the hands, and two pails, one with the peeled

tomatoes, and the other with the waste, go back on the traveling table. The Tomatoes go to their bin and the waste to a vat below. The "filler" is a machine with a plunger. It is shaped like a coffee-mill—that is a hopper tapers down to the spot where the can is placed. The cans go in a chute, and reach this spot automatically. The tomatoes are fed into the hopper. Down goes the plunger, crushing the tomatoes into the can. A knife cuts off the stream of tomatoes, and the can pops out on a traveling belt.

What is the "capper?"

It is the soldering machine. Six cans are treated at once, being held together by iron clamps. Six syringes project acid on the can covers. Hot steel cups or pressers, the size of the can covers or plates, descend, and a bar of solder is passed over the hot edges of the caps. These, holding the solder or descending upon it where it has fallen, make a circular movement, and affix the cover hermetically on the can. A vent hole still remains in the can.

Describe the sealing and cooking machine?

It is fifty feet long, and has two iron hot water chambers. The cans are now placed in trays on a traveling wire belt, which goes slowly through a bath of boiling water, which cooks them in eight minutes, and expels superfluous fluid. The belts arrive at a long table, where the sealers solder the vent-hole by hand. The tray full of cans is again set on the traveling belt, and descends into a shallow bath of water. If a can leaks, it sends up a bubble of water, and the workman locates the leak and mends it. Now the belt goes forward into the second hot water chamber, where it is half an hour in making its passage and the Tomatoes are thoroughly cooked. Then they dry.

How are they labeled?

The labeling machine is an inclined plane. An iron trough is covered with rubber. A can starts at the top. It reaches a paste brush which rises out of a bath of paste and wets the can. Next, the rolling can goes over a pile of labels turned wrong side up, that rises into place by a spring. The can picks up a label and rolls itself up in it. Then another paste-brush or roller

completes the job by fixing the edges of the label. As the can rolls downward, it passes under swinging levers that turn the paste daubers in their bath of paste. The can, after it has dried, is now ready for the market.

Is Corn cooked longer?

Yes, very much longer. The corn is cut from the cob by knives attached to wheels. The "filler" is different and catches the silk, nor does it have to cut off the stream, as if it were a large fruit like Tomatoes. The peeling of apples, peaches and pears also differs with the case in hand, but the perfect organization of labor over the old kitchen methods has produced wonderful results.

What are Plums?

A well-known fruit of secondary importance. They are of all colors and sizes. California offers the most beautiful specimens on our markets, although the Green Gage and other eastern varieties are worthy of mention with the best. If we call the Apricot and Nectarine offsprings of the Peach, we must go further to the Plum, for the structures of the fruits are much alike.

What are Prunes?

French Plums that have been dried and otherwise cured. The crop is a leading one in Southern France.

What are Dates?

They may be called Asiatic Plums. They grow on the Date Palm, a typical tree of the tropics. The Date is rich in sugar and gum, and is a leading article of food in Barbary, Arabia, and Persia. For our market, the Dates are pressed into a mass called "adjoue," which may be cut up and sold by the pound. The Arabs soak the pits in water and feed them to cattle. [See illustration at head of this chapter.]

What is the Currant?

A highly popular, hardy, low shrub, which yields a large quantity of fruit of various colors—red, white, black, etc. The botanical name is Ribes. The little berries hang in clusters like Grapes. The household article called jelly is usually considered

best when made from Currants. They are made into pies when green, and when ripe are eaten with sugar on the table, the white ones being best for this use. In the great cities, the season is short, the price always good, and the distribution, which used to be in drawers, like Figs, is now carried on in small, square boxes. Currant jelly is imitated by meat packers, and vast quantities of the imitation are put on the market.

What are Cranberries?

An important marshy crop of bright, pink berries, a little smaller than cherries. In stewing, these berries turn to the deepest crimson, and the tough skins are usually strained away, leaving a jam or pure jelly. The American people eat cranberry sauce with roast turkey, and there is a prodigious market for the product at Thanksgiving and Christmas. The berries are used as a regular winter dessert where large numbers of men are boarded. The great crops are from Wisconsin, New Jersey and Cape Cod. The two shapes are called bell and cherry. Cranberries are packed in barrels and sold by the quart. They keep as long as may be necessary, and may be taken as sea-stores. The original name was Crane-berry. The high-bush Cranberry has no commercial value. The Russians make a wine out of Cranberries.

What are Melons?

They are remarkable for the diversity of their size, shape and taste, and are divided into ten tribes. It is said that Columbus brought them to America. We use two kinds—the watermelon and the musk melon. The commercial importance of both is great. Atlanta is the centre of the leading watermelon trade, and melon trains leave there for all the cities east of the Missouri. The garbage attending the consumption of melons in great cities is one of the leading problems with which the health authorities deal. Canteloupes are generally preferred to the larger musk melons. When the timber land of the West was first cleared, the melons that grew along with the corn are the boast of the generation that is passing away. Fresh watermelons are justly famous for their refreshing and health-giving qualities in the hottest weather. It seems probable that the melon of the

Romans was serpent-shaped. The botanical name of the great tribe of Melons is *Cucumis Melo*. That is, the melon is a Cucumber. The Cucumber, in turn, is a Gourd. From this you may judge that the Gourd tribe is worth numbering.

What is the Citron?

It is a melon much resembling some small kinds of watermelons. It is mottled like large serpents and grows nearly spherical. It is not eaten like the ordinary melons, but is cut open, its inner parts thrown away, and the pared rind is preserved in various ways. The rinds of watermelons are similarly preserved. When cut in small cubes, after preparation in sugar, this fruit is highly edible, and is used in mince pies, cakes and candies.

What is the Gooseberry?

It is a very familiar but somewhat unimportant relative to the Currant in our gardens. The true name is Groiseberry, from *Kroes*, frizzled, or prickly. Gooseberry pies are eaten, but Gooseberries are not an article of commerce to any great extent.

What is the Pineapple?

It is a well-known but remarkable fruit that comes from the tropics. A large cone, weighing from one to six pounds, topped with flowery plumes, and surrounded with leaves of the cactus order, contains a woody pulp filled with juice of a high and desirable flavor. The cone is pared or cut free of its leaves and harsh skin, and thin slices of the inside are covered with sugar. The fruit is also preserved well in cans. Pineapples are especially useful in diphtheria and throat disease, as the juice has a cutting and clearing acid.

What is the Fig?

Of all our dried fruits, except the Raisin, the Fig easily leads in public estimation throughout the northern climate. It is cultivated in California, but fresh Figs are not liked as well in the Northern States or in England as the dried ones. The Fig, in fact, improves with kneading and packing. The best come from Smyrna. They are put in thin, wide boxes, and the

Turkish word "Eleme," which we see on the finest kinds, means "hand-picked."

What are Cocoa-nuts?

One of the most serviceable products of the world, furnishing to the people of the tropics cloth, food, drink, oil and vessels for household use. The nut grows at the top of a beautiful palm. It is especially cultivated for export in Ceylon. (See chapters on Butter and Soap.) Although cocoa-nuts are seen in our fruit stores and on our fruit-stands, we think their use has diminished so far as purchase for eating is concerned. But the confectioners and bakers use dessicated cocoanut more than ever, and it makes its way into many of the pies sold at the city lunch-counters.

Name some other well-known fruits and confections.

The Paw-paw grows freely, but is not much eaten. It is borne on a tree like the Catalpa. Wintergreen berries sometimes find their way to market. They are red, and the size of currants. They grow on a low plant with laurel-like leaves that contain the oil of wintergreen, one of the favorite flavors and scents. The Pomegranate and the Persimon are fruits that are known in the Southern States, and are of the Fig order. The Pomegranate is named *Punica*, implying that it once came from Carthage.

BRANCH, WITH BLOSSOM OF HORSE-CHESTNUT.

a, Vertical section of single flower. b, Fruit. c, A single seed, its coat partly removed

COCOA-NUT PALM.

a, Portion of young spathe with inclosed inflorescence. b, Branch of spadix. c, Smaller portion enlarged, showing a female flower below and male flower above. d, Cocoa-nut e, husk cut open showing hard endocarp at f, opened to show the single seed.

Nuts.

What is the leading Nut in America?

Probably the Peanut, or Earth-nut, which grows in the ground. It is distributed everywhere, and offers to the fruit peddler one of his main sources of revenue. Like coffee and cocoanut, roasting alters its chemical character for the better. Fresh roasted peanuts, deprived of the light, dry, inner husk that clothes the meat, are a valuable food. The taste quickly discovers the stale condition of old or ill-kept goods. Peanuts require a warm climate and sandy soil, and North Carolina is the greatest producer. They are called Ground-nuts in New Jersey and in the East and "Goobers" in the South. Large quantities of peanut candy are sold.

What is the Chestnut?

This is a nut that comes with the frost. It grows in a burr, with two or three nuts together. The tree is large and beautiful, but does not bear plentifully west of Ohio, and the Eastern States furnish the western market. The Chestnut requires boiling or roasting. On account of its thin shell, it is easily attacked by insects and mould, and soon becomes unmarketable. The Italian fruit peddlers, however, roast it on the streets, and in its short autumn season the Chestnut outsells the Peanut.

What are Walnuts and Butternuts?

These rich nuts grow in green and acidulous husks that never freely leave the nut. The trees are among the noblest of the forests, and, when given sufficient sunlight, spread into great

shade trees. The nuts fall to the ground after frost, and are gathered in wagons. Months are required for drying, and then the core must be burst with a mallet or hammer. This leaves the nut rough. The meat of the Walnut is fat, rich and palatable. The Butternut is a more delicate morsel, but even richer. These nuts are the particular luxury of the farm houses on winter nights in timbered regions.

What is the Hickory nut?

There are two kinds, the shell-bark and the pig hickory. The shell-bark hickory is a monarch of the forest, and this hickory nut is nearly as large as the walnut. The husk, however, comes off in sections. Pig hickory nuts are common and cheap. The average American prefers all of these native nuts to those which still remain to be be described. The western farmer usually spares many pig hickory trees for the sake of his children, who get a great deal of good food from this source.

What is the Hazel-nut?

It is the wild Filbert, and may be considered a better nut for our uses, because it is in a fresher condition when it reaches us. The common shrub of our fence-corners is cultivated with care in Europe, and the Filbert of our groceries results. The cluster of nuts is remarkable in shape.

What is the Almond?

The Almond is related to the Peach, as the wolf is to the dog—that is, the nut we eat was surrounded by a pulpy mass resembling a Peach. It is a North African tree twenty-five to thirty feet high, which has been cultivated along the north shore of the Mediterranean. It flowers in the spring and produces fruit in August. The best Almonds come from Spain. The Almond is ground by bakers and made into the famous Maccaroon, which to be good must bend and not break. Almonds are served on the banquet table at the close.

What is the Brazil nut?

This magnificent nut does not export well, but the people of the Orinoco River are justly proud of their product. The tree is one of the tallest and handsomest. As many as fifty of the

large three-sided black nuts may be contained in a single pod or shell, which has six compartments. The meat is full, white, and very rich. As the oil both absorbs and ferments easily, the nut is rarely in its prime condition on northern tables, but science will undoubtedly improve the manner of its distribution.

What is the English Walnut?

It does not resemble the American Walnut very closely, nor is it so rich or free from tannin. But it is more easily cracked and presents a shell that is less rude and more cleanly. It is therefore to be seen on banquet-tables from which the better native nuts are excluded. All the imported nuts lose in taste by their voyage and the time that must elapse in distribution. They are kept at all groceries, and over ten million pounds of Walnuts and Filberts are imported each year.

What is the Pecan?

A Southern or Mexican Hickory-nut. Its shell is a little thicker and harder than the shell of a chestnut. The meat is in two lobes, long, like a Butternut, less oily, and very full of tannin—so much so as to warn the palate. Pecans, however, seem to be slowly winning their way in the northern market.

What is the Pistachio-nut?

It comes from Sicily and Syria, and grows on a turpentine tree. It is the size of the Filbert, and is remarkable for its greenish meat, which colors Pistachio ice cream.

Spices, Etc.

What condiments are nearly always present on our tables?

Black and red pepper, vinegar, oil and mustard. In city restaurants a small dish usually holds grated horse-radish in vinegar. Pepper and salt are served in small individual metal tubes or boxes. The foreign restaurants serve black pepper in a machine which grinds what is needed for the plate. Salt cellars are also still in use.

What is Pepper?

It grows on a Pepper-vine in Sumatra, Java, Borneo and Malaysia. The vines are trained on trees or shrubs, and are allowed to grow four years before a crop is gathered. The berry grows in the fashion of a red currant, on rather longer stalks, with the size of the fruit tapering to little ones at the end of the cluster. The berries are gathered green, and dried on mats in the sun. This turns them black. White Pepper is made by soaking these berries until the outer skin peels off. Long Pepper is a product of the same vine. Americans use a great deal of Pepper—particularly on their meats.

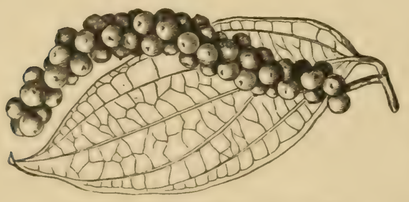


Fig. 64. THE PEPPER PLANT.

What is Red Pepper?

Red Pepper, called also Cayenne Pepper, is the principal condiment in all hot countries. The plants which bear the

various kinds of Red Peppers bear no botanical relation to Black Pepper, but are often large triangular red pods. The pods may be bottled in vinegar, which will absorb a high degree of their pungent property. It is said that even the birds of the tropics resort to these vegetables for a tonic that will arouse their digestion, and die if they are deprived of this food. Our Pepper sauce and Tobasco sauce are made by steeping small Red Peppers in vinegar.

What is Mustard?

A very ancient condiment. It was also used by the first doctors whose names have reached us. In 1720 Mrs. Clements, of Durham, England, invented the present method of preparing table Mustard, and having pleased the taste of George I, the article attained a popularity it has never lost. The small round seeds are ground and the husks are separated from the flour. Black and white Mustard are mixed with wheat flour or starch in adulteration, and it often happens that such a preparation sells best on the market. There is a great consumption of Mustard in saloons where free lunches are dispensed, and wherever cheese, especially Schweizerkase, is served on the premises.

What is Horseradish?

It is a nasturtium. Its large white roots are sold by the vegetable gardeners and farmers, and may be grated at home. It is sold in the prepared form. Horseradish is much used on raw oysters. It is good for all skin diseases, the Grippe, etc., and well liked by all old and experienced people. The leaves are frequently eaten as potherbs—or "greens" as we say. There is a Horseradish Tree in India, which is another thing. Evaporated horseradish is much stronger than the liquid preparation.

What is Ginger?

One of the staple condiments of the American kitchen. A pot of Canton preserved Ginger or the dried roots themselves will best describe their odd shape. The root travels in the ground and forms nodes or tubers, which are more tender than the stalk-root. For this reason it is called a *rhizome*. Ginger has a similar name in Sanscrit, Greek and Latin, which means "horn-

shaped." There is a mountain in India called Gingi, because it is credited with bearing the first Ginger roots. Although India introduced the plant, the best comes from Jamaica, and its essence is sold as one of our principal hot weather medicines.

Fig. 65. CHINESE GINGER PLANT.

What is Canton Ginger?

A sweet preserve of this bulbous root. It is put up in small spherical jars of various sizes, and shipped from China. It is boiled and cured with sugar. The price has cheapened in late years, and the demand for it has increased.

How is Ginger prepared for the kitchen?

The plant must grow a year. It is then pulled, scalded, peeled, dried in an oven and ground into flour. It is then black Ginger. If it is dried in the sun it is white Ginger. The root is sold to housewives for use in preserves, such as tomatoes, but for use in baking the ground Ginger is nearly always purchased and in small quantities. Ginger bread and Ginger cakes form an important item in childhood, and are never despised by grown people. Ginger is principally starch. Beside its peculiar oil, it contains acetic acid, potash, gum and sulphur.

What is the Clove?

It has been called the *nail* by nearly all people who have known it. Clove is *clavus,* nail, in Latin. It is *kruidnagel,* spice-nail, in Dutch. The Clove as we see it, is the unopened bud of a flower. It grows on a large evergreen tree which Sir Stamford Raffles described as "of noble height, somewhat like the bay, composing by the beauty of its forms, the luxuriance of its foliage, and the spicy fragrance with which it perfumes the air, one of the most delightful objects in the world." The odor of Cloves is so marked and agreeable, that most people can recall it to their imagination, and the faintest trace of its presence is detected. In this way, comparatively few trees scent the world.

How are Cloves prepared?

They are gathered unripe or unopened, and dried in the sun. The round ball is the corolla surrounding the stamens, etc., and the shaft or nail is the calyx tube. The Portuguese discovered it on the Molucca Islands in 1511. The Dutch, by cutting down trees, tried to restrict the trade, and when the product came too fast to Europe, they burned their stores. But despite this policy, the cultivation of the Clove began all over the tropics, and the Dutch lost their monopoly.

I see that Cloves never cost so much as Nutmegs and Mace.

It is because of the extraordinary fertility of the Clove. A tree will live one hundred and fifty years, and when it is full grown it will bear sixty pounds of Cloves. The product, therefore, must always be larger than the demand.

What are the principal uses of the Clove?

It comes whole or ground, and our housewives and cooks use it in both forms. Cloves are stuck whole into pickled Peaches. The ground form is used in mince pies, and even Gingerbread is often "proofed" with Cloves. Americans do not like this kind of spice in their leading foods. In medicine, the oil of Cloves is used for nausea and to stop the toothache by killing or benumbing the exposed nerve. Cloves are at hand in all drinking-places, and are used for the breath.

What are Nutmegs and Mace?

Here we have again a fruit like the Chocolate, Peach, etc. It is as large as a Pear, and Pear-shaped. The fruit dries and splits in two parts. A nut is exposed. This nut is gathered, and dried over a low fire for two months. It is then cracked open with a mallet, and the shell is discarded. A sheaf is exposed, which is Mace. Next is the Nutmeg. The word is an English and French corruption of musk-nut, from Low Latin *nux muscata*. The Nutmeg is treated in lime to preserve it from insects and to sterilize it, but this process is held to be unnecessary.

Where are Nutmegs grown?

The Barda Islands furnish nearly all the supplies, and the price is kept high. The first Nutmegs came from the Moluccas.

along with the Cloves. Like the Cloves, they escaped the Dutch into all the tropics, but have not flourished. There are three crops in a year, the last in April. Unlike the Tea, the final gathering is the best. The Mace is red, but grows yellow in baking. The Chinese like their Nutmegs to come in the shell. The East Indians also preserve the big pear-like fruit. The Nutmegs are assorted, and the little ones are ground and the oil of Mace is expressed. It is called Nutmeg Butter.

Do we use Nutmegs largely?

Yes. More Mace comes to the United States than to any other nation, and about every fifty inhabitants use a pound of Nutmegs in a year. Nutmeg is the favorite flavor for apple sauce. The housewife has a small implement which holds a Nutmeg and carries with it a grater. This Nutmeg may be grated into pies, cakes and puddings. Mace is used in pickling, in mince meat, and wherever Cinnamon can be added.

What is Cinnamon?

It is the Kinnamon of the Bible, the Phœnicians and the Greeks. Western tongues have softened the C. Our best

Fig. 66. BRANCH FROM A CINNAMON TREE.

qualities go by the name of Saigon in Cochin-China, but the plantations of Ceylon are famous over the world, and *Cinna-*

STRIPPING CINNAMON BARK AND PACKING FOR MARKET—CEYLON.

momun Zeylanicum is the name of the small tree from which the bark we use, is gathered. Cinnamon bark is peculiar in this, that though it imparts its aroma readily to liquids like vinegar, it does not soften or grow edible, like Mace.

Describe a Cinnamon plantation?

Open glades of the forest are chosen, as the little trees require protection and a rich, light soil. Cinnamon-peeling begins in May after the rains, and lasts till November. The bark is slit, cut across, and the strip is peeled away. It is then soaked to remove the outer rind of bark. It is rolled in quills about three feet long, and sometimes smaller quills are pushed inside. The air, at cinnamon harvest, is loaded with the pleasant aroma, and the harvesters make the season a festival.

What else may be said of Cinnamon?

It is notable for the agreeable pungency of its flavor, and is a strong invigorant and anti-spasmodic. There is camphor in its roots. Rich men sometimes burned grate fires of Cinnamon, as when Charles V came to Fugger's house, and Fugger burned the bonds in a Cinnamon fire. The Cinnamon fruit yields a fat that was made into candles for the King. Cassia is an inferior grade of Cinnamon. Cinnamon is a sharper flavor of the same taste as Nutmeg, but it cannot be so truly imparted to cookery. In mince pies, in pickles, and in some preserves, however, its true value is obtained. Foreign countries use it in plain cookery much more than we do. Cinnamon trees have left their traces in the Eocene rocks under the soil of America.

What is Allspice?

It is Jamaican Pimento. Like Black Pepper, it is a small berry, gathered unripe and dried in the sun, but instead of growing on a vine, it comes from a small tree that reaches twenty feet in height. It contains the flavor of Cinnamon, Nutmegs and Cloves, hence its name of Allspice. The flavor is less pungent than that of the spices which it resembles.

What is the Caraway?

It is the small aromatic seed of a plant that is cultivated in

Europe and America. A common form comes from the confectioner's, where every seed has been surrounded with a rough coating of sugar. The Caraway seed is prized in rye bread by many foreign races, and many such loaves are seen in America. Brewers as well as bakers use the seeds.

What herb-spices do we use?

Sage, Savory, Thyme and Marjoram. These are dried leaves and stems, something like Tea, but dried stem and all. Sage is put in Sage Cheese. Where meats or fowl are stuffed, one of these herbs is nearly always grated into the filling. Mutton and turkey, particularly, require expert seasoning of this order. All these native dried herbs are sold at our groceries. There are many constitutions, however, with which these herbs do not accord, whether it be on account of their coarse and insoluble nature, or the volatile oils with which they are flavored.

Describe a Mince-Meat Factory.

The Mince-Pie which is served in public places to-day, is made of a preparation which comes on the market in square boxes of twelve ounces each. About fifteen million pounds are used each year, mainly in the cold season. The meat is cut in strips and boiled in a cauldron jacketed on the inside with steam pipes. It then goes to the chopping machine, which has a revolving table on which knives play up and down. In a batch of two thousand pounds of mince-meat five hundred pounds will be chopped beef. On another chopping machine five hundred pounds of dried apples are also chopped. A spice-room contains two grinders, and here allspice, nutmegs, mace, cinnamon, cloves, ginger and pepper are all ground separately and stored in barrels. Citron is chopped like the apples.

How is Mince-Meat mixed?

The mixing-trough is capable of holding two thousand pounds of mince. The five hundred pounds of meat go in first, the five hundred pounds of apples next, then layers of chopped citron, picked raisins and currants, then a layer of sugar, then fifty pounds of mixed ground spices. On top of all a few gallons of good apple cider are poured. Now a gang of strong men with shovels begin the mixing, which is kept up until the mass is

comparatively dry. Allen's dry mince meat is the standard product. The mixture is shoveled into trucks, and stands for a certain time. Next it goes on a traveling belt. This passes the packing table, where girls, working with their bare hands, fill the little boxes. By a motion of the foot, a press comes down on two boxes at a time, and the mass is made very compact. The lid is put on, the box is put in a pasteboard case, the case is wrapped in paraffine paper, and the packers put it in the wooden box for the market. At these factories over three hundred and fifty thousand pounds of spices are used. The product finds favor in Europe, and is bought by the best Parisian cooks.

What spices have now passed out of commercial use?

Ginger-like plants known as Cassamuniar, Zerumbet and Zedoary, and clove-flavored products called Cullilawan bark and Clove bark. Cullilawan was also sometimes called Clove bark. These groups were displaced by the superior flavors of the true Ginger and true Clove.

What is the hygienic effect of spices on food?

It is probable that physicians do not look upon high seasoning in temperate climates with any degree of favor. The spices nearly all hail from hot countries. The methods of cookery and of the thrashing of grain have vastly improved, so that the healthy palate no longer has the need of the "relish" that once was called for. Spices destroy bacilli, but they delay digestion. Dr. Carrasso's discovery of the value of the inhalation of Peppermint oil for consumption has done much to displace the use that was once made of the oil and essence of Cloves. It is a good rule not to eat a dish that does not *look* good. Again, if it *tastes* good it will *probably* digest. But it is human nature to eat day after day, a dish with a certain "relish" long after the original satisfaction of tasting it has been dulled.

In what way does the Bible treat of spices?

Nearly always, in connection with religious and funeral rites. Spikenard, a sweet grass, was the favorite perfume for anointing oil and for incense. At Exodus 30: 22, there is an extended

passage concerning the use of spices in the tabernacle of the congregation, showing the high esteem in which Myrrh, Cinnamon, Sweet Calamus and Cassia were held. Frankincense was a fragrant gum exuding from an Arabian tree. The Stacte mentioned was the purest form of gum Myrrh. The Onycha, spoken of in the same passage, was a shell fish that fed on Spikenard. When its shell was burned it emitted an aromatic odor. The Galbanum was a gum, procured from a Syrian plant, and was an important ingredient in the holy incense. Where David uses the beautiful figure of the "oil of gladness," at Psalms 45: 7, the succeeding passage is doubtless in the same highly poetic sense: "All thy garments smell of Myrrh and Aloes, and Cassia, out of the ivory palaces, whereby they have made thee glad." It may not be amiss, to recall to the lover of Hebrew poetry, that in place of rhyming or keeping exact rhythm the bard of those ages was expected, having expressed himself in one figure, like "the oil of gladness," to parallel the sense of that figure in different poetical words—hence may be seen the words, "they have made thee glad." Spikenard was the favorite perfume used upon the cerements of the dead, as in the sepulture of the Savior.

Coffee, Tea, Etc.

What is Coffee?

It is the seed of a red, juicy berry that grows on a small evergreen tree. There are two kinds of trees or shrubs, *coffea Arabica* and *coffea occidentalis*, although it is said that the plant has varied under domestication, and that more than three-fourths of the world's coffee-trees are the offspring of a single plant sent from the Dutch East Indies to the Botanic Gardens of Amsterdam, in 1690. Small plants from its seeds were distributed in the West Indies. Hence the shrub was transplanted to Brazil, and to-day there are six hundred million trees growing in Brazil.

Where does the name come from?

Probably from Caffa, in Africa, where the shrub grew wild. The Turks, who first used it, call it *quahuah*, pronounced *quaveh*, but also apply the word to wine, and to a restaurant—as we say Cafe, which is French for *coffee*.

Where is Coffee chiefly cultivated?

In South and Central America. At the World's Fair costly and beautiful buildings were erected by Brazil, Colombia, Guatemala and Nicaragua, in which the culture of Coffee was typified, and its results shown in many interesting ways. The South America Coffee, having originally come from Rio Janeiro, popularly takes the name of Rio, and sells at about twenty-eight cents a pound in the middle West, according to cost of freight.

What is Mocha and Java Coffee?

It comes from Arabia, Java and Ceylon. The berry is fatter than the Rio berry, and the aroma rising from the decoction or from the ground roasted berry is finer. Less than one-fifth of the Coffee used by the non-producing world comes from Asia.

Why are the Arabian and Javan Coffees so highly prized?

Because the soil, the frequent rains and the brilliant sunshine impart to the plant and to its seed a certain fragrance not secured elsewhere. The usual mixture in America, where costly Coffee is used, is two-thirds Java and one-third Mocha. As Mocha is better liked abroad than in America, it is generally understood that little genuine Mocha comes over, and that our Mocha comes from Javan soil. It may be said that no better Coffee grows than that of Java.

What is the annual production?

South and Central America and the neighboring islands ship about nine million six hundred and twenty-five thousand bags, or one billion, two hundred and seventy million, five hundred thousand pounds, valued at $240,625,000. Asia ships one million six hundred and twenty-five thousand bags, or two hundred and fourteen million, five hundred thousand pounds, valued at $48,750,000. Europe takes about six-tenths of this production, and the United States consumes far more than any other other nation. On the Coffee market, the "Rio" grades are known as Rio, Mexican, Maracaibo, Santos and Guatamalan.

What is the history of Coffee?

A manuscript in the National Library at Paris, states that Coffee was known in 875, A. D. An Arab writer remarks that Coffee was brought to Arabia from Abyssinia about 1500, A. D. by a learned and pious Sheikh. It is from the port of Mokha, in Yemen, that the berry was first shipped generally to the world, and it is said that none of the picked berries of this true Mokha get out of Moslem countries. Mokha enjoyed the Coffee trade of the world for two hundred years. When coffee-houses reached Constantinople, about 1550, they excited religious opposition, as was the case also when they extended into Christian

capitals. The first London coffee-house was opened by a Greek, Pasqua Rossie, in 1650, so that it took a hundred years to get from the Golden Horn to the Thames. Twenty-five years later Charles II, issued a royal edict against public coffee-houses, as breeding-places of sedition. It may thus be deduced that the Pilgrim Fathers at Plymouth, Mass., and the Cavaliers at Baltimore knew nothing of Coffee. This was true as well of Tea and Cocoa, for all three came to Europe nearly together.

Describe the culture of Coffee.

Sloping hillsides above the sea are the best places for coffee orchards. The seeds—that is, Coffee—are first sown in a nur-

Fig. 68. THE COFFEE PLANT AND ITS PARTS.

sery, and when the plants are a foot high they are set out-doors in rows about six feet apart. If left untrimmed, the shrub

would grow to a height of twenty feet, but it is trimmed to eight feet, the branches being trained out laterally. The orchard, when in full bloom, is white and fragrant, and lives nearly fifty years. Doubtless the fame of the Arabian coast as a land of fragrance arose from the presence on its hills of the Mokha plantations.

What follows the white flower?

A bright red berry, resembling a cherry, with a pulpy body and two pits in a pod or cyst. These berries group themselves close to the stalk. These pits are the Coffee. The bushes bear good berries the third year. These are picked and fed into a machine, which separates the pits. The wet pits are spread on frames to dry, and the cyst or pod, which is very light, is beaten or winnowed off. Children sort the pits or bean as the Coffee is called, and it is then ready for the big bags which we see in groceries. A tree will yield from one to three pounds of Coffee, so that there must be nearly a billion coffee-shrubs in existence and under cultivation.

How does Coffee reach the consumer?

It takes about thirty-five days for a consignment of Coffee to reach Chicago from Rio de Janeiro, and the freight is about sixty cents a bag of one hundred and thirty-two pounds. It arrives at the wholesale warehouse in coarse gunny sacks, and goes to the top of the building, like the wheat in a flour-mill, where it is stored in bins. Along one side of the room is a row of roasters. These roasters are ingeniously moving hollow cylinders, with many little holes. These cylinders, when loaded with raw Coffee, revolve and twist slowly over a furnace fire, which is controlled by an air blast. All the grains are roasted alike, and the heat is cut off at the proper moment. Each variety of Coffee grown on earth requires a different amount of roasting, and the master-roaster is an expert of the highest order.

How is it served to the groceries?

It is now customary for the grocer to grind the Coffee for the purchaser, who buys only small quantities at a time. The aroma departs rapidly from the best ground Coffee, and some

Fig. 69. A COFFEE ESTATE IN CEYLON.

coffee-drinkers require fresh-ground Coffee each day. The wholesale manner in which Coffee is now roasted, has improved the average quality, which for many decades was bad in both America and Great Britain. The Centennial Exhibition of 1876, where Vienna bread and Coffee were for sale at high prices, awakened a keen desire for progress in the art of preparing this beverage.

How may Coffee be served on the table?

The scientists say it should not be boiled, nor should any foreign substance, such as egg, be added. The least economical method is by infusion—pouring hot water through the grounds. Excellent Coffee can be made by a decoction begun in cold water. Let the grounds and water be surrounded with boiling water—as glue is cooked. As soon as the grounds have settled to the bottom the Coffee is ready for the table, and the sooner it is used, the better. The older the unroasted Coffee, the better, like wine.

What is the effect of Coffee as a drink?

It stimulates the nerves and blood vessels. It has a slightly greater food value than Tea. It acts adversely on the liver and kidneys, and is so powerful as a nerve tonic as to be unsafe as a beverage where sleep is not easy to obtain at all hours. It should be only moderately drunk.

Has it any other use?

Yes. It is a valuable disinfectant, and for that reason the roasting of Coffee at home is a good thing. Freshly ground Coffee will correct the odor of damp places, and even the boiling of Coffee in a house improves the condition of the air.

With what substance is Coffee adulterated?

Chiefly with chicory, or succory. The roots of this plant are dried, roasted and ground with Coffee. This is done largely in Europe, where a taste for chicory has been cultivated. There is not much chicory in Western America. Our clever adulterators sell what they call "cerealized coffee," that is, it has been mixed with rye or other grain that roasts somewhat like Coffee.

What other adulterations are practised?

Coffee foundries have been established, where the bean is

cast from various substances, the form of coffee being simulated. These cast coffees are then boiled in the extract of Coffee, and colored, and when the product is mixed with ordinary genuine Rio, the cast bean or berry is perhaps the one that would be least suspected. These practices flourish best at times when a world-wide speculation in coffee is going forward, when the price of the crop is advanced several cents a pound.

Can you name an American authority on Coffee?

Francis J. Thurber, of New York City, one of the best known grocers of the United States, has written a book of four hundred and sixteen pages, entitled "Coffee, from Plantation to Cup," well illustrated. This covers the subject, and the author writes from personal experience.

What is Tea?

It is, with Coffee, one of the two principal drinks of Americans. While men usually prefer Coffee, women are inclined to Tea.

Fig. 70. THE TEA PLANT.

Tea, as we buy it, is the dried and broken leaves of an evergreen shrub which grows best in China, but also in Japan, India, Cey-

lon, and many other parts of Asia. The plant grows from four to six feet high, and bears white blossoms that resemble wild roses.

What beautiful flower is a close relative of Tea?

The Camellia. Linnæus established two kinds of Tea—*Thea Bohea* and *Thea viridis* (green), but the English learned, in 1843, that both black and green Tea are made indifferently from each plant. A big Tea tree has been found in Assam, which botanists think is the parent species of all cultivated varieties.

Is Tea a hardy plant?

Yes. It may be likened to wheat in that regard. It is cultivated in Japan as far north as thirty-nine degrees of latitude, and southward through Java, India, Ceylon, South Africa, Australia and Brazil. But the climates that best conduce to its growth are the most fatal to Europeans.

Describe a Tea-Farm or Garden?

The methods of the Chinese have been altered by the Indian cultivators, but the fame of the Chinese Tea is undiminished, and all other offerings, however highly extolled by their manufacturers, fail to meet the popular demand. Good as is the Chinese Tea, the very best never goes outside of China, and the second best goes only to Russia, and is exported through the northern gates of the Great Wall. The tea-farm is usually small, on the sloping side of small hills, far from the mouth of the river. The seeds are planted, and the shrub grows three years before any leaves are plucked. The shrub is now established and throws out young shoots or "flushes" in profusion. A garden will contain about fifteen hundred plants to the acre, and about three hundred pounds of finished Tea will be produced.

How are the leaves plucked?

By hand. The Tea of each leaf has a name. The little leaf on the tip of the shoot is flowery pekoe (from *pak-ho*, white hairs); the next larger leaf is orange pekoe; the next, still a tender leaf, is pekoe; the next is pekoe souchong (from *siaou-chung*, little plant); the next is souchong, the next is congou (from *Kung-fu*, labor); and if there be a still larger leaf on the shoot, it is bohea,

(from *wu-i,* the mountains in Fuh-keen). These shoots will come out four times a year. The most fragrant picking is the first, in April, which is hyson (from *yu-tsien,* before the rains, or from *Tu-chun,* flourishing spring). Other pickings follow in May, July and August or September, the latest being the poorest. Oolong means black dragon, and other names usually apply to the region of growth, for the souchong of one province may be as sweet as the pekoe of another.

What are the commercial names of Tea?

They are Chinese appellations, sometimes translated, but usually merely imitated in sound. The great grades of Tea are four—black, green, brick and perfumed.

How are these grades subdivided?

The blacks are named after the size of the leaf—that is, the three pekoes, the two souchongs, congou and bohea. The greens are called gunpowder, imperial hyson, young hyson, hyson skin and caper. There are black and green scented Teas and two sizes of bricks in brick Tea.

How is black Tea prepared?

The leaves of the shoots are all plucked together and exposed to the sun and air on circular trays. Here a slight fermentation takes place. The sugar of the leaf unites with a volatile oil. There is a loss of tannic acid. The leaves become flaccid, and are spotted with red or brown. By the odor arising, the tea-maker knows just when to begin the roasting which the leaves undergo, for it is to be understood that the alkaloid principle for which the human race craves, is nearly the same in Tea, Chocolate and Coffee, and is obtained in all cases by the action of fire and from evergreen trees or shrubs. After the roasting in an iron vessel, the hot leaves are kneaded or rolled in the hands, and juices are squeezed out. Finally, when they have been several times manipulated, the leaves are dried in sieves over a charcoal fire, and in this last stage, but owing to the hand manipulation, they turn black.

How is green Tea prepared?

There is no drying in the sun. The leaves are hurriedly

placed in the iron vessel, then rolled in the hand, and then dried in the same iron vessel, but constantly stirred and fanned. The green color follows as a result of this rapid evaporation, no alteration taking place in the essence called chlorophyll. This Tea is not exported. The green tea sent out of China is colored with gypsum and Prussian blue.

How is brick Tea prepared?

It is made of broken leaves, stalks and fragments of large leaves. This is a staple article of family use in an area of Central Asia larger than Europe. Sometimes it is slightly pressed and packed in skins, but often it is solidly cast or pressed into hard cakes, with gilt characters on the side, like India ink cakes. The tribes of Central Asia stew brick Tea in milk with salt and butter, and eat it as a vegetable. Great quantities go with the yearly Asiatic caravan, from Pekin to Moscow. Brick Tea also serves as money over a vast region.

How is scented Tea prepared?

The finished Tea, either black or green, is mixed with odoriferous flowers until the Tea has taken up the perfume. It is then sifted and immediately packed and excluded from the air.

Is pekoe made only of the tenderest leaves?

Not exactly. The finished Tea is sifted, and the qualities are named rather according to the size of the fragments than in any other way. Many pieces of souchong can thus enter the pekoe.

Does adulteration thrive?

Not since the success of the Indian tea farms. It is as cheap to fabricate from the tea-plant as from any other herb, and the customs authorities at London and Liverpool are very expert in the detection of fraud. But the finer the alleged grade of Tea, the stronger is the inducement to cheat. It is also to be averred that the brands of Tea thrown on the market from the new tea-farms, are grossly inferior to the average supply that used to come from China.

What commercial brands of Tea are sold in America?

Six different qualities and prices of Basket Fired Japan, Sun Cured Japan, Moyune (Amoy), Gunpowder, Assam, Young Hy-

son, Oolong and Orange Pekoe, Monsoon, white or yellow label, and the new Ceylon Teas. Various other Teas with special names of no significance are offered. It is to be seen that the finest Pekoe grades do not come to market.

What is the history of Tea?

Strangely enough, Marco Polo, our first historian or observer of Chinese ways, does not mention Tea. In China, the name is *Cha,* but the Amoy dialect has it *Tee,* whence English merchants got the name which survived, although it was first known at London as *Cha* or *Chaw.* All agricultural and medicinal knowledge is assigned, in China, to the traditional Emperor Chin-nung, who reigned in 2737, B. C., and he discovered the virtues of Tea. A Chinese writer named Lo Yu, who doubtless lived under the Tang dynasty, 618 to 906, A, D., says of Tea, that "it tempers the spirits and harmonizes the mind, dispels lassitude and relieves fatigue, awakens thought and prevents drowsiness, lightens or refreshes the body, and clears the perceptive faculties."

When did Tea reach Europe?

It came back as the result of Vasco's voyage around Cape Good Hope, but the Portuguese did not take kindly to the beverage. When the Dutch Company was set up, trade began in earnest, for the officers of the company were not slow to acquire the habit of drinking *Chaw.* When Tea first came to England, it sold at from $30 to $50 a pound. In September, 1658, the following notice appears in the *Mercurius Politicus:* "That excellent and by all Physitians approved China Drink, called by the Chineans *Tcha,* by other nations, *Tay, alias Tee,* is sold at the Sultaness Head, a coffee-house in Sweetings Rents, by the Royal Exchange, London." Old Pepys drinks *Tee* in his celebrated diary, and in six years' time has it at home, as a medicine for his wife's cold.

Was Tea-drinking opposed?

Yes. With the same arguments that went against Coffee. It was called a base, unworthy Indian practice. The doctors assailed it as the cause of hypochondriac disorders. But in the end it fastened on the northern countries with a greater hold than

Coffee has attained. It is the great Russian drink, and the Russians excel in the convenience, elegance and skill with which they prepare it. In fact, their apparatus is at last to be seen in many parlors of America.

What great change took place in the Tea-trade of America?

The opening of the Pacific Railroad in the United States put the middle west directly into connection with China and Malaysia, and now the fine wheat flour of our Pacific coast goes to China in exchange for good Tea, and the tea-gardens of Ceylon and India are finding wide markets in the Mississippi Valley.

What is Chocolate?

Chocolate is the Mexican name of the cacao-tree, and Cocoa and Chocolate are two commercial preparations of the same substance—cocoa or cacao beans.

Where does the Cocoa tree grow?

The best grows in Venezuela, and is shipped from Caraccas. All the tropical countries produce the tree.

How is the Cocoa Bean secured?

The tree looks like a young cherry tree, but it bears a sort of cucumber, with ten ribs, of a yellowish red color. In the pulp of this fruit are twenty or thirty nuts called beans, like almonds, of ash gray color. Inside the nut-shell are two meaty lobes, called nibs, from which Cocoa and Chocolate are made. The shell is more easily broken than an almond shell.

Describe a Cocoa plantation.

The small cocoa trees, from nurseries, are planted between rows of food-yielding trees, for the plants require shade. The cocoa trees are seven or eight years in coming to their growth, but one man can attend to an orchard of one thousand trees. The fruit is gathered in June and December. Only a pound and a half of seeds can be taken from one tree. The tree grows wild, also, and the wild fruit is marketable. There must be frequent rain, and the soil must be moist all the time.

How is the fruit gathered?

The trees carry buds, flowers and fruit in all stages at th same time. In Caraccas there is the crop of St. John and tne

TEA ROASTING AT YOKOHAMA. (See page 189.)

DRYING COCOA SEEDS (See page 193.)

Christmas crop. The workman, armed with a long pole, on which is a knife, shears, or a prong, selects only the pods that are fully ripe. The pod is from seven to ten inches long. The stem is leathery. The nuts or beans lie in rows in a delicate pink acid pulp. The pods are gathered into heaps on the ground and left for twenty-four hours. They are then cut open and the seeds are taken out and drained of the moisture of the pulp. They are carried in baskets to the sweating-box.

Then they are to be treated like Coffee and Tea before they go to market?

Yes. Fermentation without great heat is desired, and sometimes, instead of the box a trench is dug and clay is thrown on the mass. But whether the sweating take place in box or trench, the mass must be often stirred. It is in the Caraccas orchards that the greatest skill is used in securing the proper degree of fermentation, which in favorable weather can be finished in two days. When the nuts are exposed to the sun, the best ones take on a warm reddish tint.

How does Chocolate reach a great city?

In bags of nuts with the shells on. The nuts go to the top floor of the chocolate factory, where they are roasted with as much care as Coffee. The roaster is a cylindrical machine which turns slowly over a coal fire. The nuts must have just so much heat, and must be cooled in an exact manner, or their flavor becomes inferior.

Where are the greatest Chocolate Factories?

In Holland, and it is said that the Caraccas output does not come largely to America. But the great chocolate makers of the world erected buildings at the World's Fair of 1893, and by their operations stimulated the demand for high priced goods.

What is the cracker-and-fanner?

It is the machine to which the roasted nuts go. This is a loosely-set grinder in a fanning-mill. As the nut goes through the iron disks, its light shell is broken off, the air blast sends the shells out of the way, and the meats or nibs fall in a box below.

Are the nibs ground?

Yes. They are fed into a hopper and travel to the mill on the first floor. Here the nibs pass between grinding-stones, and a thick chocolate paste results. This is "premium" Chocolate. It is stirred in kettles, cast in cakes, and wrapped in tin foil for the market.

How is Cocoa Butter made?

The chocolate-paste from the grinding mill is treated like the oleomargarine. It is formed into little cakes wrapped in canvas, and layers of these are stacked under a hydraulic press. (See Oleomargarine.) The cocoa bean or nut is over half fat, and all this fat comes away.

What use is made of this Cocoa Butter?

It is used by confectioners and for the very finest grades of soap. The American factories cannot supply the demand, and over 2,000 tons are imported each year.

What is Cocoa?

It is the residue after the oil has been expressed. The little cakes, taken from the press, are broken with a mallet and are ready to be ground again. Now instead of a paste, a fine flour is secured. For drinking purposes, this flour is packed in tin boxes, and is ready for the grocery. If it is for the candy-maker, the flour goes to a mixer, where after sugar and flavor have been added, the mass goes through rollers. Cocoa is preferred as a drink because the average consumer cannot tolerate so much oil as Chocolate contains.

Is Chocolate also sweetened and flavored?

Nearly always, in Europe; less frequently in the American factories. The little cakes from Holland and Paris, that are so tastefully wrapped, are prepared by secret formulas, and coated with cocoa butter. Heat, cold, sugar and perfume play important parts in the processes. Hot rooms and refrigeratories change the temperature of the mass rapidly. For confectioners, the American manufacturers make up raw bricks of ten pounds each.

How did Cocoa get its botanical name of Theobroma?

Linnæus had eaten the seeds, and knew the possibilities of Chocolate as a food. He honored it with a name which meant food for the gods, from the Greek *Theos*, god, and *bromos*, food.

Do Americans use Chocolate largely?

Yes, but as a confection. About 50,000,000 pounds of Chocolate are consumed annually, and 10,000,000 pounds of Cocoa are bought for drink. Coffee and Tea remain the prime favorites, and the people refuse to detect in Cocoa the principle or stimulant which theyfind in the two other drinks. Yet chemistry reports a surprising likeness between the alkaloids of all three. For pulmonary complaints, where digestion remains fair, experiment should be carefully carried on with Chocolate, on account of the large ratio of fat which it carries.

Meat, Etc.

What changes have taken place in the production of animal food?

The business has fallen into the hands of a few firms. Refrigerating cars and ships are made to carry fresh meat to any distance, and prepared or pressed meats are delivered at all the inns of Europe and America. Ham, turkey, chicken and other meats are potted and sold in cans. Turkey and chicken are canned in slices. But the great staple of this kind is doubtless pressed corned beef.

Where are the greatest sources of this manufacture?

At Chicago, in the Union Stock Yards, although branch-houses have been established in all the large Western cities. The Stock Yards are in the south-western quarter of Chicago, and are bounded by Halsted street on the East, Ashland avenue on the west, Fortieth street on the north and Forty-seventh street on the south. The great community that grew up about this industry was long known as the Town of Lake. Dexter Park was at the Stock Yards in early days, and here the horse Dexter made his fastest time of 2:17¼.

How are Swine slaughtered?

At the leading packing establishments you are furnished a uniformed guide. He takes you to the pork house first. The Swine are brought into the room in a pen mounted on low wheels, a dozen animals at a time. A man seizes a hog by the hind leg and loops on a small steel chain. The chain is

BRANDING AND DEHORNING CATTLE AT A ROUND-UP IN TEXAS

connected with an overhead railway, and the animal is instantly suspended head downward. Thus hanging, his throat is cut, the blood flows from the carcass, and it passes into the cleaning machine, where knives take off nearly all the bristles. Again the carcass is suspended, and it is ready for cutting. In three minutes from the time the hog was caught, its meat is boxed for delivery.

How are Beeves killed?

Next you are taken to the beef-killing building. Here is where the steer called Judas operates. He leads the company of cattle to the movable pens, and as they pass in he returns to secure further recruits. Each slaughter-house has a Judas. The movable pens come into the room with only two victims at a time. Their heads are forced into position and a terrific blow with a steel hammer is dealt between the eyes. Instant insensibility follows. The animal is suspended, and passes rapidly before the various butchers, who do the work apportioned to them with great skill and speed. The carcass is laid down in order to remove the hide, again hung, cut in halves, and travels onward to the cooling rooms by means of the overhead railway.

I have heard that the Jews must kill their Beeves separately.

Yes. The victim must be examined, approved and killed by a Rabbi, or priest. The guide will take you to the Hebrew department. Here you see a low, heavy-set man, with a long beard and a solemn air. The animal to be slaughtered is brought into the room by a long rope, which passes through a steel ring fastened firmly in the floor. As the rope is drawn tightly, the animal's head is pinioned fast to the floor. Another rope is attached to one hind-leg. The Rabbi has now thoroughly washed and re-sharpened his huge knife. He approaches, and with one stroke cuts the jugular veins. The carcass is then hung. Swine are kept as far as possible away.

How are Sheep killed?

Just before you see the Rabbi, you go to the large room where mutton is prepared for the market. The process is similar to the hog-killing. In removing the pelt, care is taken

that the wool do not touch the meat. The carcass is washed and tagged.

How many animals are thus killed at Chicago?

About 2,500,000 beeves and calves, nearly 6,000,000 swine, and over 1,500,000 sheep each year. In an establishment such as we have described, there can be killed in one day, 20,000 swine, 4,500 cattle and 2,500 sheep. Nothing is wasted, meat, glue, beef extract, butterine, tallow, pepsin and fertilizer are the principal products. The horns are polished for ornamental furniture.

What are Cow-boys?

The popular name for the herders of the West. Cattle for many years were driven in vast herds across the plains, following a beaten path from Texas to Montana. The cattle were branded with the owner's mark, and the round-up showed how each proprietor's property stood. Animals without a brand were known as "mavericks." The cow-boys rode horses or ponies called broncos, a California name. A man who could train a young or wild bronco was called a bronco-buster. Eastern and European people have become familiar with this class through the Wild West Shows of the last twenty years. (See "The Story of the Cow-Boy," by E. Hough. D. Appleton & Co.)

Was this meat-raising business controlled?

So it was alleged. Although the cattle-ranchers of the West complained of low prices, it was many years before there was a decline of price in meat, and Congress made several investigations. Foreign governments have regarded the growth of American meat industries with jealousy, and have alleged many reasons for cutting off the trade. At last, the President was authorized by Congress to retort. If our meats were debarred, he was to prohibit the entrance of the leading article of that nation's commerce. This did some good, but difficulties still menace the trade. We export a vast amount of pork and lard. Our cured hams go all over the world.

Pickles, Vinegar, Etc.

Where are the largest Pickle Factories?

In Pittsburg, Pa. It is said that one establishment bottles nearly five billion cucumbers each year. The Pickle Factories establish salting houses in the cucumber districts, and the vegetable gardeners carry wagon loads to great cylindrical vats. The cucumbers are put in brine, and sometimes tank cars carry them eastward. Some of the Western cities pack these pickles in barrels, but even this class of work is largely done eastward of Chicago.

What takes place at the Factory?

The salted pickles are washed in warm running water, and so treated that they will keep their green color. They next are poured into a very odd-looking sorting machine. Imagine a revolving shaft placed at an incline toward the floor. On the first part of the shaft put a very large cage with bars near together. As the cucumbers revolve in this cage the littlest ones fall out; the bigger ones pass onward toward a second cage with larger intervals between the bars. A third cage lets out cucumbers a size larger, and at the end, the biggest ones come out together. Thus, beside the machine, four baskets are filling at once.

How are the cucumbers bottled?

They now pass at once to rows of girls at tables, who use a pair of slim wooden tongs. With these they arrange the cucumbers around the sides of the bottles in even rows. After this careful arrangement, the vinegar and spices are

poured in, according to the formula of the factory. The bottle is then corked and covered with tin foil. The label is put on by girls in another room. Sweet pickles are made by pouring into the bottle a sweet liquid.

Are other vegetables pickled at these factories?

Yes. Small onions, cauliflower, small tomatoes, beans and other products. For this purpose many steam kettles are used, and gardens are maintained for the production of choice goods and special sizes. The smallest cucumbers, made originally in imitation of the French, are popularly called "Tiny Tims," and are considered a delicacy. They are pickled sweet.

Are there Catsup Factories?

Yes. The waste from the tomato canneries was once utilized, but later the tomato was boiled to a pulp, passed through sieves, spiced, mixed, bottled and labeled. The manufactured catsup closely resembles the home product, but is usually of a lighter red color, without seeds. Although we usually mean tomato catsup when we use the word catsup, there are catsups made of grapes, currants, goeseberries, cucumbers, peppers (Tobasco sauce), mushrooms, walnuts, etc. The word came from the East Indies, and is variously spelled. It properly applies to any hot sauce.

What is Chow Chow?

It is a preparation of pickles with the addition of mustard, which in China is held in high esteem. Cauliflower is the leading or conspicuous ingredient, with cucumbers. All the spices may be added, to which mustard gives the characteristic yellow color. Chow Chow came with the Union Pacific Railroad and the Chinese to America, and has been accepted as one of the national sauces.

In fact, all vegetable things may be pickled?

Yes. Although the cucumber leads, various fruits and vegetables are preferred in different parts of the country. As we go southward, red pepper grows in importance as an adjunct, for climatic reasons.

All this is done with Vinegar. I am interested to know something of this wonderful liquid.

Vinegar, as a word means sour or sharp wine, and comes from

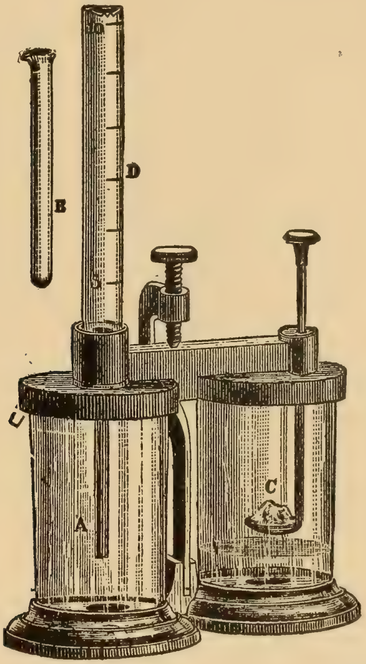


Fig. 71. TWITCHELL'S APPARATUS FOR DETERMINING THE STRENGTH OF VINEGAR.

the French (*vin aigre*). It is best known to the masses of our people as sour cider. However it be made, it is the commonest form of acid.

What is an Acid?

In common terms, to be an acid the substance must dissolve in water; it must taste sour; it must have the power to turn vegetable blues to red; it must have the power to decompose carbonates with effervescence as the carbonic acid leaves; it must counteract the alkalis, at the same time turning to salts itself.

Acetic acid (which is Vinegar) is composed of water, oxygen, carbon and hydrogen.

Still I do not know what Acid is.

Nearly all human knowledge, when thus brought to bay, must confess that it cannot go further. As we have said concerning the action of rennet in cheese, we know it does it just so, but why we do not know, nor have the cheese-makers found anything else that ferments the cheese in as good a way as rennet. That may be "personal error" or prejudice, or truth. But men, as in the case of Electricity and Darwinism, are compelled to erect working theories, and chemists frequently accept Gerhardt's theory that acids are always salts of hydrogen, and are always desirous to give up their hydrogen for a metal. [See Chemistry.]

Thus we come to an Electric phase of the question?

Yes. You may refer to *plus* and *minus* in the chapter on Electricity. Acid is Electro-negative, and is borne to the positive pole in a battery. Gerhardt believed that some materials of acids displaced one atom of hydrogen, some two atoms, some three. In this way he accounted for the three forms or more of phosphoric acid. He grouped the acids into three great types—water acids, hydrochloric acids, and ammonia acids. Owing to this Electric-negative condition of Vinegar, it may be seen how greedily such a metal as copper or lead would be attacked, and as the matter given up by the copper or lead would be a poison, a cucumber preserved in a vessel of such metal would be full of the poison. As the copper makes a green color, a pickle that is not green certainly has no copper in it, although there may be no copper in a green colored pickle.

What wonderful thing is it that keeps the cucumber from decomposing?

Various theories are held. Oxygen, the most plentiful element in nature, is negative and goes toward the cucumber, oxidizing it, or rusting it. Pasteur demonstrated that the oxygen was here aided by microbes, and that decay would be extremely slow or perhaps impossible where microbes were

excluded. In water, where there is not so much oxygen, the process is one rather of solution than what we call decay. But possibly the minute organisms are aiding in the action. Now acid is hostile to life germs. The attack of the acid on the entire structure of the cucumber is energetic, and the result is this—that we entirely lose the taste of the vegetable, and find ourselves eating cells that are apparently nothing but acetic acid. This acid dissolves the starchy and fatty food in our stomachs, destroys germs and, moderately used, gives good results. It is likely that our race, or a good part of it, craves sour things because of the need of destroying the bacilli that might otherwise overcome the life of the human tissues.

How do we obtain our Vinegar?

Wine was the first material. The wine stood till it was sour. Apples were our great source in earlier days, and cider Vinegar is still considered the best and safest for table use. The barrels of cider stood in the cellar, and sometimes "mother" was added from old Vinegar, and thus the fermentation was hastened.

What kinds of Vinegar do we have now-a-days?

Red-wine Vinegar, the strongest and costliest; cider Vinegar, the most popular; white wine Vinegar, which does not come from wine at all, the common form for use at the pickle factories.

Describe the manufacture of white wine Vinegar?

Corn and rye arrive in cars and go to the top of the Vinegar Factory, where they are stored in bins. A spout leads from the bin to the boiler far below. This is a closed steam cauldron, which carries a pressure of about sixty pounds. Into this vessel about one hundred bushels of shelled corn descend, and water is added. In two hours it is a mush or mash, and is blown in a tube upstairs into the mash-tubs, which hold eight thousand gallons each. Now fifty bushels of malt are added.

What is Malt?

It is barley or other grain steeped in water until it germinates, then dried in a kiln, evolving the sugar; or it may come wet

and finely ground to the mash-tubs. The mass of mash and malt is now agitated by revolving paddles, at a temperature of one hundred and forty-eight degrees. The cooking of the corn in the boiler separated the starch; the addition of the malt and the warmth turns the starch to sugar, and there is a sensation of the presence of molasses. After several hours of churning, certain pipes in the bottom of the vat are filled with cold water. and the yeast is added.

What is the Yeast?

A copper-lined kettle holding two hundred gallons is filled with malt, rye and water and the mass is boiled. A yeast ferment is added, and soon the big two hundred gallon yeast is made. This big yeast is "planted" in the mash-vat, and the whole body is passed in pipes to the fermenting tanks, where for seventy-two hours the sugar "works" and the alcohol is liberated. A link-pump now carries the mash to the still up stairs. Steam is forced through the mash and into the still. As the alcohol goes with the steam into a pipe that passes through the still, cold water on the outside of the pipe condenses the alcohol and it runs down the pipe into a vessel. The mash now is ready for the cattle that eat it.

What is next?

The generators. These are tall wooden tanks or leaches, filled with beech shavings. As water goes through ashes and makes lye, by percolation, so the alcohol is now to percolate through the shavings. But the chemical change that takes place here is owing to the oxidation of the alcohol, and the shavings are only for the purpose of offering the widest surface for the oxygen of the air to reach the alcohol. When alcohol and oxygen meet, acetic acid or Vinegar is the result. Several floors are covered with generators. The alcohol trickles in at the top; the Vinegar trickles out at the bottom of each tank. It stands a while in tanks and is then barreled. A bushel of grain makes about four gallons of white wine Vinegar. It is sharper than apple cider Vinegar.

Is the process of making Cider Vinegar also hastened?

Yes. Hard cider Vinegar is passed through the beechwood shavings in the generators, and the product is allowed to stand in old whisky barrels, which ripens it.

Is Red Wine Vinegar also generated?

Yes. The wine for the generators comes from both Ohio and California. In years of enormous grape crops, this use insures the vineyards against absolute waste, however cheap the price.

Salt.

What is a Salt?

A Salt is the result of an Acid and some other matter when they combine, and this resulting substance must be different from either the Acid or the other matter (the base, as the other matter is called).

What is our table Salt?

A union of Sodium and Chlorine. Sodium is a white metal, never found in its pure state. Sir Humphrey Davy first isolated it. Chlorine is a gas that has a green color, hence its name, from *chloros,* Greek for *green.* It also is never found free.

Then our table Salt is not a Salt?

You are right. It is the Chloride of Sodium. There are three other elements—Fluorine, Bromine and Iodine—that are capable of uniting with metals and making substances much like sea Salt. Hence the four are called *Halogens,* or salt-producers, from the Greek *'als,* which meant both *Ocean* and *Salt,* because the ocean was salt.

What makes the ocean so salt?

Evaporation of its water, and nothing else. All lakes, if they lasted long enough, would become salt by evaporation. The ocean is least salt where the icebergs are melting, and where the Amazon is pouring in. Its Salt keeps it from freezing at 32 degrees of Fahrenheit. Its Salt renders it more buoyant than fresh water. It is therefore better fitted for navigation.

But how is it known that Salt is composed only of Sodium and Chlorine?

Many ages of investigation passed before the present view was adopted. Salt itself was known and spoken of familiarly in the earliest writings of our race. The Greek and Latin philosophers, although sometimes giving salt a different name, busied themselves seriously with its nature. Dioscorides, the great traveler and botanist of the first century, speaks of its peculiar cleavage, and notes the difference between sea-water Salt and Rock Salt. The alchemist Geber, in the eighth century, made many experiments to refine it. In 1810, however, Sir Humphrey Davy produced pure Salt by burning the metal Sodium (an element, see Chemistry) in the gas Chlorine (another element), thus authorizing its present scientific name of Chloride of Sodium or Sodium Chloride.

What foreign matter is most frequently present in our Salt?

Water; but it does not make a chemical union with Salt. As in the case of Quinine (page 263) and Silk (page 360), water comes and goes, the water molecule attaching itself but loosely to the salt molecule. Water and air are both semi-mysterious bodies, and give opportunity to the imaginations of chemists, but it seems certainly erroneous to claim, or even to opine that water, in associating with Salt, divides its own molecules, and makes a new distribution of Sodium, Chlorine, Hydrogen and Oxygen atoms, as long as the water is not dried out of the Salt. Wherever this may be taught, it must be error. With Silk, Tin does make such a union, yet water does not. This water can be "conditioned" out of Silk, but Tin would not dissociate so easily.

What of the Spectroscope?

Burning Salt (page 221) gives the Sodium double yellow line, which is by far the most prominent feature of all the spectra. In spectra of earthly things the Sodium double-line is bright. As Sodium is seen burning on the sun, the same lines are black. Salt is so generally present that it is somewhat difficult to keep the Sodium double-line out of spectra of other elements. (See last page of this volume.)

What are beds of Rock-Salt?

They are the deposits of former seas, for all the land has been under water, however high it may tower above the sea-level. At Cardona, in Spain, there is a precipice of Rock Salt four or five hundred feet high, overlooking a valley. It is quarried, and needs only grinding for table use. Salt deserts and marshes occur in America, Russia, Persia and Abyssinia. The Abyssinian salt was used for money, a block decreasing in value as it neared the quarries or mines.

What properties does the Chloride of Sodium possess?

It is white and sparkling when ground as we see it. It is bluish and crystalline as Rock Salt. It has a sharp taste, but not sour, nor spice-like. It does not alter its composition in a red heat. It will not dissolve in alcohol, while cold water will dissolve very nearly as much Salt as will hot water. The salt crystal is usually a cube, but at high temperature, the process of crystallization becomes more rapid, and the form is a hollow pyramid.

But what other great property does Salt possess?

It preserves against decay. It is called a detergent, because it cleanses. The cucumbers will keep in the salt vat, but they will absorb so much Salt that only a little bit could be eaten. The meat that we eat after it has been preserved in brine must often be soaked in water. The absence of what we call decay may be caused by the balance of electricity, or static condition; or by the presence of a metal or gas fatal to the life cell or bioplasm; or by the absence of the life cell.

What is this Life-cell?

Scientists are not yet able to deny that there are things that are alive and things that are dead. (See Life.) Strangely, when a thing does not decay, it is dead; when it decays, it has come to life—life has been added, according to Pasteur's demonstrations. By life, we mean a movement of some combination of Carbon, Oxygen, Nitrogen and Hydrogen. That movement is not electrical, but willful, eccentric, animal, to some extent human—that is, it is *alive*. Again, that movement is as much a

PASTEUR IN HIS LABORATORY.

thing of itself as the action following the introduction of the rennet in the cheese.

Cannot the scientists make this Life mixture?

No. They can only make the dead mixture. The living mass of Carbon, etc., called a life-cell, may be seen, under the microscope to move, its atoms going among each other. In an unsalted piece of dead meat, this living mass would surround a particle of tissue and absorb it; presently an atom would start out away from the mass, and become a new mass, a process called cell-cleavage. In some fatal diseases, these masses multiply in number and with rapidity almost beyond credence.

What does Salt do?

In certain quantities it arrests that action. The mass itself dies. But there may be some Salt present, for the human blood, and all blood, which is filled with life-cells, contains Salt, and tastes of Salt. Until man shall know just what happens, his theories will work badly enough to show him that they are all faulty. With life thus tolerant of Salt, it must follow that the meat-packers have found other preservative substances more valuable, and a mixture of boracic acid, sodium phosphate, saltpetre and common Salt, will preserve meat in the proportion of only one teaspoonful to the pound of meat.

Is Salt taken apart?

Yes. Its Chlorine is needed for bleaching powder, for electric accumulators, etc. Its Sodium is needed for soda in soap, for glass-making and for other alkaline purposes. England manufactures caustic soda and carbonate of soda in vast quantities, and our soap factories import nearly 100,000,000 pounds a year. It all comes from Salt.

What is its greatest use?

Simply as a condiment or seasoning in our food, and in the food of animals. It is one of the necessities of life, and every nation has access to it, either at the ocean's edge, in mines, or by salt springs or wells. The Smithsonian Institution exhibits the large quantity of Salt present in the average man of one hundred and fifty pounds.

Where are our leading Salt-Works?

The greatest are in Michigan. New York, West Virginia and Ohio are vast producers. Salt was the earliest manufacture in American History, for the colonists at Jamestown, Va., before 1620, had established Salt Works at Cape Charles, and sent salt to the Massachusetts Puritans in 1633. In 1689, salt was made in South Carolina, and sea-water establishments were in operation on the coast of every State from Maine southward. Solar evaporation at Cape Cod, Mass., and Key West, Fla., has flourished for a century.

What of the interior States?

The French Jesuits were familiar with the Onondaga Salt Springs, near Syracuse, N. Y., and the White settlers boiled five hundred bushels in 1788. The French and Indians used the springs of Southern Illinois in 1720. The Kentucky springs were used before 1790. The first salt manufacture in Ohio was in 1798. In Western Pennsylvania the business began in 1812. Rock Salt was discovered in what is now West Virginia at a very early date. The Great Salt Lake of Utah measures fifty by twenty miles, and its waters are one-fifth Salt. Salt lakes of smaller size abound in the Western deserts, especially in California. Missouri, so rich in every valuable mineral, has vast resources of this kind, and nearly every State could be a large exporter.

Describe the Onondaga works?

The springs are in low marsh lands, in which wells of two or three hundred feet are sunk. Out of these wells the salt water is pumped to the reservoirs. The brine holds from seventeen to twenty per cent. of Salt. It stands in the reservoir to let the sediment settle, and alum is added to hasten this action. Coarse Salt is secured by running the brine out of the reservoirs into tanks that are only six inches deep. The tanks near Syracuse cover hundreds of acres. Here the sun will leave fifty bushels a year in a tank only sixteen by eighteen feet in size.

How is fine Salt secured?

Parallel rows of vat-cauldrons, set in brick "blocks," extend the length of the works. Each cauldron will boil one hundred

gallons of brine. By the process of the manufacturers, whether by precipitation or otherwise, the sulphate of lime, oxide of iron, and chlorides of magnesium and calcium are taken away, and when this fine Salt is barreled it weighs fourteen pounds less to the bushel than the solar Salt. The State of New York owns the wells, and receives a royalty on all Salt produced. Seven-eighths of the product are made by boiling. A cord of wood or a ton of coal will secure forty-five bushels of fine Salt.

What developed the Michigan works?

The economy of uniting the lumber and salt industries. Eight thousand square miles of salt-producing rock, about 800 feet under the surface of the earth, promise an illimitable supply of brine. Wells have been sunk as far as 2,000 feet. The first one was put down in 1859. The benefits of lake navigation are secured. Steam from the saw mills evaporates the brine by day, and the sawdust and other waste furnish fuel at night or at other times. Barrels for packing may be made from rejected timber. Through all these arrangements, and on account of private ownership, the works have surpassed all other American establishments in product.

What is the history of Salt?

Such a history is of course as old as that of the creatures who cannot live without Salt. The relation of Sodium and Salt was at once known. Sodom, the city, meant *burning* in the Semitic tongues. The name of Sodium is Natron in German and older languages, and the Egyptians valued their Natron marshes as well for embalming purposes as for Salt. Salt pits are mentioned in Joshua, and in Leviticus the Jews are ordered to make no offering without Salt. Babes were washed in Salt. Salt was the symbol of fidelity and death. Conquered cities were sown with Salt. Treaties were concluded with the eating of Salt.

The Spectroscope.

What is the Spectroscope?

It is an instrument, variously made, for the examination of the light that emanates from heated bodies.

Why is that light to be studied?

Because every Element emits a different set of rays or undulations, and all the Elements may be recognized by the lights and shadows which they cast.

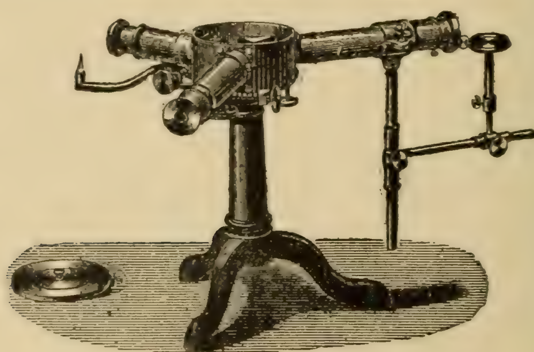


Fig. 73. A SPECTROSCOPE.

What is a Spectrum?

If you darken a western room in the afternoon while the sun is shining, and then make a round hole in the window curtain, so that the sun can shine through the hole, a line of sunlight will go through the hole and follow a straight line to the wall, where a round, bright spot will appear on the wall. If you hold

a three-cornered bar of glass—a prism—with one of its sharp corners up, so the line of light will go through at a point in the "blade" of the prism a little from the top edge, the round, bright spot will disappear from its previous place on the wall,

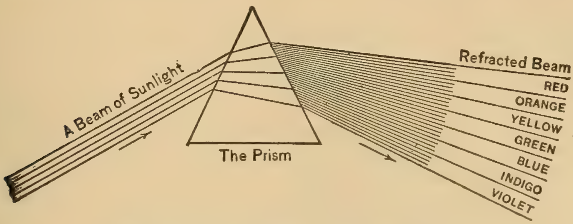


Fig. 74. OBTAINING A SPECTRUM.

and, falling several degrees, will become a "long spot with round ends" that is, the disk will be stretched out. But this is not all. The top of the spot will be red, the middle yellow, the bottom blue, with all the shades and tints interspersed between. It was found, forty years before the X Rays, that just above the red end (in the dark) bodies could be heated, and just below the blue end (also in the dark) bodies could be chemically affected, so that there were X Rays even in those days. But these outside and non-luminous rays were not X Rays like those which Doctor Roentgen discovered in 1895. (See X Rays.) The long spot on the

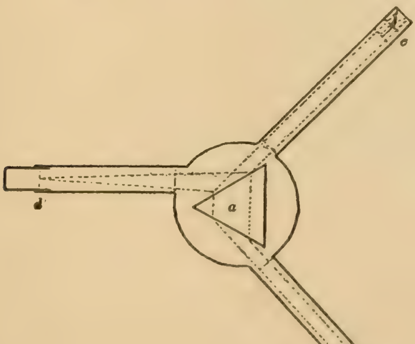


Fig. 75. PRINCIPLE OF THE SPECTROSCOPE.
(a.) Prism. *(b.)* Tube through which the light passes. *(c.)* Eye-piece. *(d.)* Scale.

wall is the sun's Spectrum. Two such spots would be Spectra (plural). Study of this spot is Spectral Analysis. Newton began the investigations.

What did the scientists think about the long spot?

They concluded that the prism had made a long row of spots on the wall, each overlapping the other. So they began experimenting with knife-cuts or slits in the window curtain, to see if they could not get also a row of slit-like bright places on the wall. But these experiments only demonstrated that light went through the prism in every degree of refrangibility, and that the divisions of color we make with our eye are only illusory, or at least rude.

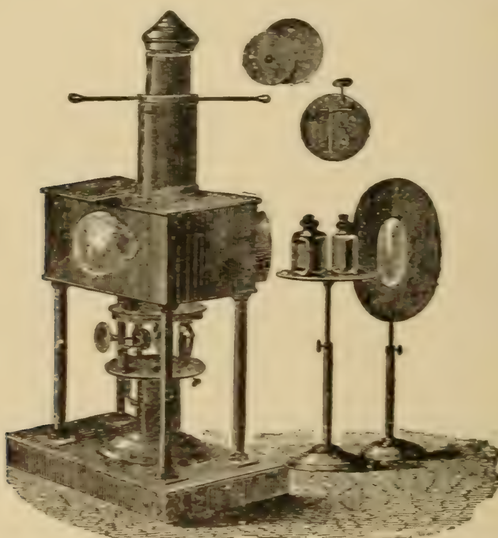


Fig. 76. SPECTRAL APPARATUS FOR SHOWING SPECTRAL LINES ON A SCREEN.

What is Refrangibility, Refraction, etc?

When you put the oar of a boat in the water, the oar seems bent. The oar represents a line of light sent into the water. It bends. A line of light sent through the prism bends downward and spreads downward, and the blue end of the Spectrum or rainbow spreads more than the red end. If the line of light

were a cable of fine wires, the red wires would bend the least, the blue wires the most. All that is refraction.

What is Diffraction or Interference?

An important phenomenon of which the people have much less opportunity to know. If a coin be held before the hole in the curtain through which the sun shines, the coin's shadow on the wall will have a ring or rings around it. Theory accounts for these rings on the basis that light is a force sent through the atoms of the air or ether. When the atoms meet obstructions they must alter their motions, and after the atoms or the forces rejoin, the effect of the collision must remain and manifest itself. To get at our point, if light sent from all burning substances do not act in the same way—if it act differently for different substances—then the shadows and light places on the wall will differ for every burning substance. Newton discovered the peculiarities of diffraction. Fresnel (see Search-light), accounted for them on the theory of moving atoms of ether.

What have shadows to do with the Spectrum?

It is with these shadows that we deal entirely. After the opticians had made their slit in the window-curtain and obtained lines of light instead of disks of light on the wall, they found also lines of darkness running across the Spectrum. That is, if a hair-comb were laid lengthwise on the Spectrum, the lines of darkness would run the same way as the teeth of the comb.

What were these dark lines first called?

Fraunhofer's Lines. And it was further found that if the light let in at the slit were not the sunlight, the Fraunhofer Lines would be *bright* instead of dark.

How was the Spectroscope made?

As the experimenters desired to avoid refraction of an unequal kind, they laid trains of prisms to correct the refraction. They set lenses before their eyes to magnify the Fraunhofer Lines. Finally, they made gratings on speculum metal which caused diffraction or interference, and by another means separated the ray of light into its light and dark cross lines. Machines were made by which the speculum mirror or grating showed ten,

twenty, fifty, one hundred, and at last one hundred and forty thousand lines in an inch of space. A ray shining on these lines met each one of them and set one hundred and forty thousand series of

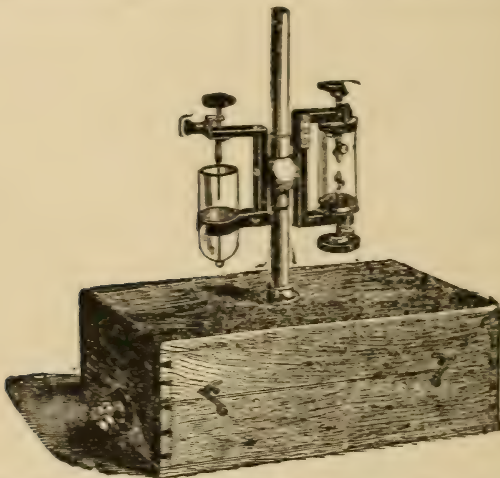


Fig. 77. BROWNING'S SPARK CONDENSER, TO MAKE SPARKS FOR SPECTRAL ANALYSIS.

atoms in motion, making light and darkness. By these gratings, the lenses are dispensed with, and the image of the Spectrum, with all the Fraunhofer Lines, can be thrown on a screen. The more closely the lines are ruled, the more the Spectrum is spread out, extending over a space of many feet.

What is the law of the Spectrum?

Every Element, when heated to a glowing vapor, emits a light that when sent through the Spectroscope, shows a Spectrum with Fraunhofer Lines different from the lines on the Spectrum of any of the other Elements. The Spectrum is divided into one hundred and forty thousand places to the inch by the recent inventions, and any variation of that degree is at once easily noted on the screen. This offers opportunity for seeing as many Fraunhofer Lines.

Name some Fraunhofer Lines.

Zinc flame shows three blue lines and one red line crossing the

Spectrum at certain places. Copper sends three green lines. Hydrogen has double violet lines. Iron has many lines. Nitrogen and Manganese show three and Calcium one. It was from the Indigo-blue line of the Spectrum that the chemists discovered Indium, the metal. These lines are bright.

But the lines on the Sun's Spectrum are dark?

That was explained by Kirchoff, one of the greatest of the Spectroscopists, in 1859. The Spectrum was then well mapped, and he identified the dark line at Fraunhofer's D on the sun's Spectrum, as the same line which was bright in the Spectrum of the Element Sodium, when its light was sent through the Spectroscope. In those days, the Spectroscope was a three-tubed, star-shaped apparatus, such as we illustrate, and by letting in the sun's light and the Sodium's light at the same time, he made the Fraunhofer lines fit on one another. In this way he suggested the presence of Sodium, Iron, Calcium, Magnesium, Nickel, Barium, Copper, Zinc and Cobalt on the sun.

Why are the sun's lines dark, while the same Elements, burning on earth, throw bright lines?

It is explained on the theory that Sodium, in burning on the sun, makes a shadow by comparison with the vivid power of the light around it. The Persian poet imagined the glory of God to be such that the sun itself was His shadow.

Fig. 78. HERRMANN'S HEMOSCOPE, or BLOOD-TESTING APPARATUS.

Did the study progress?

Very rapidly. Professor Crookes, of the celebrated X Ray tubes, was one of the most successful experimenters, succeeding in lighting the Elements by the electric spark and noting the map of their Spectra. In 1861 he thus discovered Thallium.

What wonderful result followed?

The Spectroscopists found lines on the sun's Spectrum that were not present in any light given on earth. They therefore named the two sources of these Lines Helium and Coronium.

Helios is the Greek name for the sun. In 1895 Lord Rayleigh, who had isolated the Element Argon, a gas, announced that in isolating Argon he had found the Spectrum of Helium, and soon Helium was isolated by several chemists. Thus one of our Elements was first recognized at a distance of ninety-five million miles from the earth. No Gold is found on the sun.

Are the Stars studied?

Yes. They have been classified into stars like our sun that show many metals. Capella, in the Constellation Auriga, shows many metals. There is a large class like Sirius, that show more gas than our sun, principally Hydrogen. The third class show Iron, and their Lines are like those of the sun's spots. They are believed to be cooling into a molten condition.

What is the most interesting result of the Spectral Analysis of the stars?

The Fraunhofer Lines in a star's Spectrum shift as the star comes or goes. When the star is coming, the Lines move toward the blue end of the Spectrum; when the star recedes, the Lines move toward the red end. The color of the star, too, changes with its motion. If a green star moves toward us most rapidly, it turns violet. If it recedes at enormous rate, it turns red. For two days and ten hours the star Argol, in the Constellation Perseus, comes toward us as fast as twenty-six miles a second; then for the like period of fifty-eight hours it recedes at the same speed. Some stars move one hundred miles a second. The Spectra of the moon, planets and comets, are like the Spectrum of the sun—a mirrored showing from the great source of light.

Have Americans led in these Spectral experiments?

Yes. Professor Rowland, and the scientists of the Johns Hopkins University, have brought the Spectroscope, with its gratings, to a perfection almost incredible, and without doubt, the number of Elements and the peculiarities of the Carbon Compounds will be investigated with important results to the human race.

What theory prevails as to the motion which the Fraunhofer Lines betray?

Since the sunlight sends shafts of motion of all kinds, and not

merely seven kinds, as Newton thought—that is the colors of the rainbow—the chemists and Spectroscopists now are forced to theorize that the atom of each Element sets up a motion within itself, and that the Interferences and Diffractions take place in the ether that plays inside the atom. This is believed because two atoms of different Elements—say a molecule of Salt (Chlorine and Sodium) make a Spectrum of their own, showing that the ether moves in the molecule, as it does in the atom. What makes the ether move?—that is, what is Light?—must be better answered in the future than it is now.

What results from the developments of the Spectroscope?

It follows that the knowledge of mankind concerning Matter spread from the four hundred lines of Fraunhofer to the one hundred and forty thousand Interferences for each inch of the Johns Hopkins Spectrum. The secrets of each flame will be given up, the vibrations that make each dark or bright line will be scaled or theorized, the rapidity of Light undulations will be fixed within possible figures, the relation of the Electric vibrations to the Light vibrations will be sufficiently expressed, and the number of new Elements will become innumerable, until the uniform constitution of matter, as an outgrowth perhaps of Hydrogen, will be demonstrated. The imagination recedes before the labors that await our modern scientists.

Where may I read a brief summary of Spectral Analysis?

In the article Spectroscopy, in the Encyclopœdia Britannica, you may gather the main facts of the chemical Spectra, group by group, as we shall go over the ground in describing the Elements. (See Chemistry.) The importance of dealing with the Elements in groups will become apparent if we look further into the subject. It is alleged that the alloys of Gold and Copper can be told apart in the Spectroscope if they differ the one-ten thousandth of a degree.

In criminal trials, where the Spectroscopist is called as a witness, how can he influence the jury?

In the trial of Luetgert, at Chicago, accused of the crime of murdering his wife and destroying her body in a solution of

alkalis, Professor Delafontaine, Spectroscopist, testified in part as follows: "The Spectroscope is an instrument which consists essentially of a stand on top of which is a triangular piece of glass called a prism, that is enclosed in a box to which are attached three tubes. Through one of them light is admitted, a light from any flame or any source that we want to study. Through another tube we send light to show a scale by which we locate lines and colors. The third tube is one through which we look and see what there is to be seen. I have just described the plain, ordinary Spectroscope, the same that I used. Now, when we place a gas light or a candle light or a kerosene flame in front of one of the tubes, the one to admit the light, and look through the small telescope, we see a bright band of color lights, the seven primary colors of the rainbow lights, passing gradually into each other; that is called the Spectrum of white light, or the continuous Spectrum. Now, if you hold in front of that tube in a flat bottle, or in a tube, some clear liquid, more or less of the light is absorbed, and we do not see all the seven primary colors as before. Now, some liquids have the power of absorbing just certain colors and letting the others pass. Of course, where the light has been absorbed, there is a black band. When you look through you see some of the color, more or less of the rainbow, but at a certain spot, which is always the same for the same substance, there is one black band, or several bands. Some will give quite a number of lines and bands and others only one."

What did the State prosecutor next ask?

The prosecutor asked: "Do the elements or metals have distinctive colors or combinations of colors?" To this Professor Delafontaine replied: "Yes. If we take what is called a Bunsen burner—that is, a gas burner that gives a blue flame like the kitchen stoves where they burn gas, just a blue flame, and hold it in front of that tube, it gives nothing when you look through except under certain conditions of the test. Now, if you bring in that blue flame a little of the salt of say, Potassium—hold it in that flame on the end of a Platinum wire—and look through, then we see all black or nearly black, except at one place there is a bright red line. That bright red line is always at the same

place whenever Potassium is put in the flame, and no other metal gives that same line at the same place, and therefore, we say that it characterizes Potassium—that means to say that whenever we see that red line in the flame, that means that we have brought into that flame some compound of potassium, and the same in regard to Sodium. Common salt, for instance will give you a bright yellow line, which is always at the same place, never to the right or to the left. It always corresponds to some degree of your scale."

In what way could the Spectroscopist discover evidences of guilt?

The witness was asked: "How much material is necessary to make the spectroscopic test such as you have just described?" A.—"Oh, for common salt (containing Sodium), exceedingly little. So little that in fact we can hardly avoid getting in that Sodium line, because in the test here, if I shake the table it will go there into the flame; it is very hard to make an observation in which that Sodium does not show itself, but we understand that. I never figured it in fractions of a pound, but we know the fraction of a drachm is about the two-millionth part of a drachm. As regards Potassium it will require about one thousand times more of the compound to show a red line."

In what way did the Spectroscopist discover the presence of blood?

The Professor said: "Blood is a liquid in which are floating microscopic round bodies called the red corpuscles and others called the white corpuscles. Blood is red because it contains the red corpuscles. Now, those red corpuscles contain a coloring matter which is called, when the blood is fresh, hemoglobin. When blood is boiled or heated with the alkali, that hemoglobin is soon transformed first into another coloring matter, that I do not need to mention now, and finally into hematine, which remains dissolved, and it is what we call alkaline hematine. If we take a solution of the alkaline hematine in a glass tube, and hold it in front of the Spectroscope, while the ray of alkaline hematine passes through it, the seven primary colors of the

rainbow, which the white light would give, are obscured by a specific dark band, in the region of the red and orange."

In what way do such investigations become convincing to a jury?

The Spectroscope finds that incriminating Elements are present, and exculpatory Elements are absent, or *vice versa.* Thus, there was no trace of spices in the matter contained in Luetgert's vat; there were Aluminium lines in the spectrum, and it was charged that Mrs. Luetgert had worn a set of artificial teeth with an aluminium plate.

IMPORTANT CHEMICAL DISCOVERIES OF RECENT YEARS.—A temperature low enough to turn air into a liquid was attained as early as 1883. Professor Dewar's now famous demonstrations followed, and Tripler's public exhibitions of boiling a tea-kettle filled with liquid air by putting it on a cake of ice were well noticed in the newspapers. In the summer of 1898 Professor Ramsay reported to the London Royal Society the discovery of two previously unknown elements. In the air, through its liquefaction in large quantities, he discovered Krypton, which forms one-twenty-thousandth part of the atmosphere. In liquefied Nitrogen he discovered Neon. Soon afterward he discovered Metargon.

To the astonishment and admiration of mankind, a woman, Madame Sladowska Curie, of Paris, has made one of the most remarkable discoveries in the whole realm of molecular physics. In December, 1898, she isolated an Element, or at least a substance, which she named Radium. This Element either sends forth particles of matter without measurable loss to itself, or so excites the air or ether as to cause the deposit of particles of matter on affinitive substances. The atomic weight of Radium is 140. This radio-active quality had been known to exist feebly in Uranium. It seems to be one of the principles in the Welsbach mantle. (See Cerium Group, page 289.) Radium is now produced as a commercial article. One ton of the metals of the Cerium Group yield less than an ounce of Radium.

In 1899 Professor Dewar produced liquid hydrogen in visible quantities, and it froze air and oxygen. Shortly afterward he turned Helium to a liquid.

Coronium was first seen in the spectroscope, July 29, 1878, in the corona at the eclipse of the sun. In 1898 it was discovered at Vesuvius. Its line in the old scale of the spectroscope was 1474. In the new scale its line is numbered 5316.9. Professor Rowland, the originator of the great diffraction spectroscope, died at Baltimore in 1901.

In 1899 Professor Crookes found the element Monium, while exploring the ultra-violet region of the spectrum. Its atomic weight is 118. Its principal lines (new scale) are 3120 and 3117.

Madame Curie announced another element, which she named Polonium, in honor of her native land.

Two elements as ghostly as Coronium were found in 1899, in the spectroscope. The line at 5570.7 has been named Aurorium. Nebulum is an element betrayed by its two lines at 5007.5 and at 4959.02.

In October, 1899, Professor Crookes discovered Actinium.

Coronium, Aurorium and Nebulum are elements that approach to the ether, and will lead to a closer study of the present molecular theory.

The progress of discovery in these early years of the first decade of the twentieth century was hastened by spectroscopic analysis of those features of Light or Radiation which do not appear in the visible spectrum, but rather in its infra red and ultra-violet ends.

M. Sagnec, of Paris, demonstrated that, when X rays can be deflected, they become S rays.

When X rays pass through perforated metal plates, they become Goldstein rays.

The name of Becquerel rays is applied generally to the invisible radiations of certain elements. Prince Krapotkin suggests that this radiation is a characteristic of all matter.

In April, 1904, Prof. Charles Baskerville, of the University of North Carolina, announced to the Chemists' Club, at New York City, that he had resolved the metal Thorium into two elements (but this matter is not yet well established). These Elements he had named Carolinum, and Berzelium — the latter after the Swedish chemist who discovered Thorium.

Prof. Nichols perfected a Radiometer capable of measuring the heat of a man's face 2,000 feet away.

The star Arcturus shows the heat of a candle burning six miles away.

Vega, a brighter star, throws off but one-half the heat of Arcturus. Arcturus is thought to be much the farthest away from our sun.

In measurements of the distances of stars, the center of our sun becomes the station from which the operation ends

MODERN DEVELOPMENTS OF PHYSICS AND CHEMISTRY. Continuing this line of up-to-date information the questioner may be further instructed, as follows:

The study of any gas in a vacuum and under the influence of Electricity from rapid wave-making apparatus, led to the accidental discovery of the X ray. (See page 93.) But, before that time, Becquerel had discovered that Uranium emitted light and heat; this was accounted for on the old theory of an immediately previous absorption of the light and heat. When it was found that the rays of light from the kathode or negative pole of the battery in the tube were volleys of matter, scientists like J. J. Thomson, set out to measure the mass of the separate particles of the substance that was flying in the glass tube and making a light like the Aurora. or making no visible light at all. The most extraordinary thing discovered was, that these Kathode particles were 1,000 times smaller than the hydrogen atom, which in the old theory had been next smallest to the particles of ether themselves. First the reader is to know that by means of varying (charges of Electricity, with varying powers of magnets, etc., to deflect the flying) particles, a reasonably correct idea of the mass of the particles could be obtained, for negative Electricity (at least), is not imponderable, but adds to mass (as now discovered). The electrometers or electricity-measuring-apparatus gave an accurate idea of the mass of each particle. To the astonishment of everyone it was found that only full atoms of Hydrogen would fly from the positive pole in the tube, while the particles (they called them ions) flying from the negative pole (Kathode) were 1,000 times smaller. Thereupon man for the first time became aware of a power to tell how negative Electricity is different from positive Electricity. As soon as Polonium and Radium were discovered, new opportunities were afforded of investigating these long concealed processes of nature. To obtain a comparative idea of the distance to which the physicists have carried the process of separating matter, they reckon no less than millions of atoms in the thickness of the film that makes a soap-bubble.

In 1903, Sir William Crookes, perfected a spintheroscope (instrument with which to observe sparks of fire that are too small to be seen with the naked eye). Upon setting a screen of sulphide of zinc before a tube filled with Chloride of Radium, it was seen by the use of this instrument that the Radium was bombarding the zinc with innumerable particles of fire, and it is these tiny meteors that cause objects to fluoresce when Radium acts upon them. In addition to these material emanations, Radium gives off Alpha, Beta and Gamma rays (named after the three first letters of the Greek alphabet). These invisible rays will take photographs, and they will pass through substances which the meteors cannot pierce.

It was soon announced that the fiery particles thrown out radially by Radium were 1,000 times as massive as the electrons of negative Electricity, and moved at a speed of 30,000 miles a second, or faster than the speediest star in space. The reader should note that by means of the Crookes tube, the high currents, the bolometer, and Radium, man has been able to make quantitative investigations and analyses that were far beyond the powers of both the microscope and the spectroscope.

Radium, like Sodium, "keeps" best in its Chloride state (see Salt), and is thus prepared by M. and Mme. Curie. A pound of Radium would cost a million dollars' worth of labor. Radium comes from an ore called Pitchblende, and the principal mine is at Jachinsthal, Bohemia. America furnishes some ore. After all the Uranium has been extracted from this ore, the refuse, "a lumpy reddish powder," is sent by the ton to the works of M. Curie, at Ivry, just outside Paris. Here, in about two years' time, eight tons of ore yielded a gramme of Chloride of Radium—about a saltspoon full, and in day-time looking like salt. Counting the radio-activity of Uranium as 1, the Radium is refined to an intensity of 2,000 at Ivry. M. and Mme Curie then take charge of the process and refine the substances to the pure Chloride, with an intensity of 1,500,000 Uraniums. A tube of this latter substance will, without contact, kill mice, destroy cancerous growths, start ulcers on the human body, and enable the blind to see if the optic nerves have not been destroyed. Radium (the Chloride) induces temporary radio-activity in at least fifty other substances. If placed in water, the Hydrogen of the water begins to depart. Radium intensifies the brilliancy of diamonds. In the insect-world the development of moths has been delayed for four generations, thus prolonging the actual living time of the structure for three generations or so.

If the X rays are to be called Roentgen rays, the Kathode rays ought to be called Hittorff rays, for it is to Hittorff that the world of science owes the good fortune of suspecting that matter was projected from the Kathode, and that matter was projected from Uranium, leading to the hunt for Radium, and its capture in the chloride and bromide forms.

It was noted early in the history of the Kathode (Hittorff) rays, and the Becquerel rays, that the spectrum of Hydrogen persisted. Man had long hoped to reduce all matter to combinations of Hydrogen under varying changes of the two Electricities. Radium also produced a Hydrogen spectrum in its outpourings, or in their effects.

Late in 1903, Sir William Ramsay announced at London that in his experiments with Radium it had given off a heavy gas, which slowly turned into the gas Helium, and then vanished. A verification of this celebrated investigator's views would prove the old alchemists' contention, that a transmutation of matter is possible.

In 1903, the Nobel Prize of $20,000 was divided among M. Becquerel and M. and Mme. Curie.

FLYING. After 5,000 historical years of futile attempt by mankind, Wilbur and Orville Wright of Dayton, O., brought human flying into the world at Kill Devil Hill, near Kitty Hawk, Currituck, N. C., Dec. 17, 1903. Wilbur Wright was led to attempt the problems of the air after reading the works of Dr. Marey (See Photography). But this same Wilbur

Wright, who with his brother encountered the most serious risks of experimentation, never had a serious fall, and sternly discountenanced the feats of unnecessary aerial daring so eagerly applauded by the populace. He died of typhoid fever at 3:30 a. m., May 30, 1912, possibly the most universally admired of modern men. His brother Orville proceeded with his experiments, and a year later exhibited his stabilizer, which enabled him to ride aboard his biplane without, at times, touching the controlling levers. Meanwhile, advances were made in the hydro-biplane. The French continued to experiment with the monoplane, and carried large parties of passengers on one machine. In the ballooning field, the Santos-Dumont machines led to the vast Zeppelin air ships, with their numerous tragedies.

IMPROVED X RAY APPARATUS. Professor Crooke's claim for a fourth state of matter—solid, fluid, gaseous, radiant (see page 102), has not been overthrown.

Among the ingenious and useful additions to the conveniences of everyday life are the machines that now come from the electrical workshops. The frictional machine and improved X ray tube are illustrated on these pages. These efficient sets of apparatus are now put within the reach of every physician, and all may come into a direct knowledge of what Prof. Crookes means by "radiant matter." The old "static" machines were made with disks of glass, and in this way Franklin's Pane and the Leyden Jar could be made more effective; but a disk of glass cannot be revolved with safety at a rate of speed greater than 400 revolutions in one minute. To secure greater speed Dr. R. V. Wagner invented a compound mica disk, made of a vast number of thin pieces of mica, shellacked together and put under great pressure. The result is a rigid sheet or disk of mica that can be revolved with a speed of 2,000 turns in a minute. The current of electricity generated in a tube by this machine gives a fine idea of radiant matter.

Dr. Wagner has invented an adjustable focus for the X ray tube which is even more ingenious. By its means the operator can focus the X rays on the anode without risk of disturbing the vacuum in the tube. Taking advantage of the fact that magnetism acts through the glass walls of the tube, a regulating apparatus is established in the tube; the clamp is opened by a magnet and closes by a spring, and the anode is raised or lowered, or handled circumferentially, by merely turning the tube on its axis. In this way, all tubes become "pet tubes," because all alike catch and throw in one direction the maximum number of the X ray emanations.

Suppose the reader desire to see the skeleton of his arm, hand, or lower limb, or any other thing in usual concealment; he now sets the machine going, either by hand or by turning a key from a power-house; the disk turns furiously; the current is let into the tube; (by this process the Ruhmkorff coil is not needed), the radiant state of matter sets up in the tube; the Kathode rays bombard the anode, on which is a facing of platinum; the X rays are emitted, though of course invisible as yet; a fluoroscope is placed at the eyes (as the old stereoscope used to be placed); the screen of the fluoroscope is coated with barium-platino-cyanide; the one hand holds the fluoroscope; the other hand can be held between the screen of the fluoroscope and the X ray tube; now the skeleton of the hand is seen—the more perfectly, of course, as the focus obtains more and more of the splattering X rays, for they do not reflect with the regularity with regard to incidence that marks other forms of light.

Although the electrical demonstrations in this interesting operation are impressive, the current is not dangerous to life or limb, and the operator may put his hand into a thick stream of "lightning" without injury. The constant discharge of the high vibratory current, it is claimed with reason, precludes the danger of burns from the X rays.

These or similar sets of apparatus should be in every schoolhouse, in order to acquaint the scholars with the wonders of the coming Electric Age.

Our illustration gives a still simpler form of fluorescent screen, where, under a high vibratory current, the skeleton of the subject appears in clear outlines on the screen, revealing any deformity or any extraneous substance. The problems of the air, it would seem, must soon give way to the keenness of modern scientific research in the X ray rooms.

THE LIFE OF MATTER is a field of investigation that has of late found many faithful and ingenious observers, Dastre, a prominent one among them. These researches have brought back into use the ancient meaning of our word "brute"—that is, something without feeling or sensation. Animal and vegetable matter are now put in one class and "brute matter" in another. It is thought that the form of life in brute matter may be a different, lower, or arrested form. The crystal is understood to be alive, but its life-cells have not the adjustable form of animal and vegetable life-cells, and must come together in one of about six ways, while animal and vegetable life-cells may proceed on an infinite number of patterns. Nor is the crystal the only expression of life in brute matter, for it is now seen that the particles of matter travel among themselves and may journey into neighboring matter. Upon keeping gold and lead in juxtaposition for a considerable time at a temperature of 212° Fahrenheit, it was found that grains of gold had permeated through the lead for a distance so great as to compel the idea that they had moved of their own accord and were alive.

Dastre does not ridicule the theory that all forms of life-cells reached our earth through meteoric messengers, and he leans to the belief that no life-cell has so far sprung into being or action under the scrutiny of man unless it had a life-cell like it for a progenitor.

The geologists sustain a well-organized theory that life began at the poles and spread toward the equator. The rocks and fossils bear out this view. The earth for ages (as the sun now does) must have revolved much swifter at the equator than at the polar regions (all things being equal); therefore, a fluid condition was preserved near the equator for ages after solids had appeared in the north and south.

LATEST X-RAY DEVELOPMENT. The Ruhmkorff coil, and Dr. Wagner's static machine used for X-Ray work has been supplanted by a new development known as the INTERRUPTERLESS High Potential Transformer. (Ill. p. 97).

With this apparatus it is possible without endangering the life of an X-Ray tube to pass through it upwards of 200 milliamperes of current, where 30 milliamperes with the early Ruhmkorff coil and one-half to one milliampere on the static machine was considered the maximum.

This type of apparatus is supplied with 110 or 220 volts at its primary and delivers at its secondary terminals an average maximum voltage of 150,000. This high tension voltage is so controlled that small fractions of this maximum amount can be utilized. This high tension current after leaving the Step-up Transformer is of an alternating character and is rectified by the use of a mechanical rectifier connected to either a rotary converter on direct current or a synchronous motor on alternating current, so that a high tension direct current is supplied to the X-Ray tube.

To make the subject more readily understood by pupils and people with little technical knowledge we still illustrate and describe the static machine and we believe because of its simplicity it will always be a favorite in the class room.

PROF. DEWAR'S INVESTIGATIONS OF LOW TEMPERATURES. Liquid hydrogen is colorless, transparent, and has a clearly defined surface. It drops well, although it has only one thirty-fifth of the cohesion of water. It can be poured from vessel to vessel. It is by far the lightest liquid known, weighing only one-fourteenth as much as water, but a piece of pith-wood will float on its surface. It introduces man to nearly a world of solids, for, excepting helium, it is the coldest liquid known. It boils at 252.5 degrees below the centigrade zero. At 259.5 degrees it becomes solid, whereupon man has reached the lowest steady temperature yet secured. Hydrogen "ice" weighs only one-tenth that of water. On exposing liquid hydrogen to the air, the air freezes and falls to the bottom of the hydrogen, looking like snow.

Starting at the surface of the earth with air that contained only two ten-thousandths of hydrogen, then at 37 miles height there would be 12 per cent of hydrogen and only 10 per cent (instead of 20) of oxygen. At 47 miles, or 132° below zero centigrade, only hydrogen would be left of the three gases, the nitrogen and oxygen lying below. There is some kind of atmosphere as high up as 100 miles. It is at the upper heights that the helium, krypton, argon, metargon, neon and xenon gases are caught in the spectrum of the auroral lights.

These investigations strengthen the theory that the outer atmosphere of the earth and the sun are composed of similar gases. The difficulties of securing the spectra of auroras in the Crookes tubes are also accounted for.

THE BOLOMETER. Becquerel made instruments that recorded the heat of Uranium and phosphorescent light. S. P. Langley invented a machine which records the action of light outside of the visible spectrum, on both ends, and man now knows that what he calls Light is only an "island" in the interior of a region of influences that extends many times its length on each side of the spectrum. Curves in the lines registered by the Bolometer indicate what would be Frauenhofer lines in the visible spectrum.

THE PLANET MARS. Developments in the study of this planet have offered to the human mind possibly the most portentous scientific question that ever confronted it. Briefly, the problem is whether or not the Italian, Schiaparelli, by determining in his brain that there are certain triangulations with dots at the junctions on Mars, could hypnotize the rest of the race into seeing the same markings. Once about every 15 years Mars appears for many months high across the midnight sky, shining a deep red and larger than Sirius. After Schiaparelli, in 1877, had startled the world with his map of Mars, showing canals or markings that were assuredly made by design if they existed at all, the astronomers set to work to prove or disprove his observations, but as Mars rapidly receded from the region of study, it was a question whether observers saw any such thing or not. In May, 1894, Percival Lowell, a truth-seeker, author of the book "Mars," assisted by Pickering and Douglass, established an observatory at Flagstaff, Arizona, and with a large telescope, watched the southern hemisphere of Mars for a year, making nearly a thousand drawings. Lowell's map shows 288 markings—canals, dots, lakes, gulfs, continents—whatever it is desired that they be called. Draw on a sheet of paper, first a dot larger than a pin-head; then from that dot draw eight radii or spokes; cross these spokes with other triangles with a dot at each junction, and no dot ever out of place; call the spokes canals; make them double part of the year; have the double and single canals run over the "continents" as well as the seas, or cross a big lake as bridges would do—do all this so you have 288 elements, dots, marks, etc., and you have what some twenty great astronomers think they have seen. The old timers were slow to treat Mr. Lowell with the proper regard, but they erred in not acceding to his dogma that an 18-inch telescope in Arizona was better than one twice as large at Washington or in any other poor sky.

Chemistry.

What are the Elements of Nature?

The chemists have separated the Universe into something like ninety kinds of Matter. Elements have been noted in Sun or Stars before they were recognized on the earth, like Helium or Coronium. The very high and very low temperatures of modern Science have isolated much of this new Matter, but at the same time have disturbed the theory of its stability.

What is the good of knowing the so-called Elements?

If we learn the list of the principal ones, we then know that practically all other things, however misleading in name, must be compounds of two or more Elements, at least one of which we know by name or by sight.

Shall I learn the list of Elements?

Yes, of the principal ones. But first it is important to know that Carbon forms compounds with more Elements, and in more ways, than all the rest of the Elements put together, so that Chemistry may be divided into two departments—Carbon and non-Carbon, or as they are called, organic (Carbon) and inorganic (non-Carbon) Chemistry.

Name, then, some important Elements.

Carbon, Oxygen, Hydrogen, Nitrogen, Phosphorus, Sulphur, Calcium, Sodium, Potassium, Boron, Chlorine, Iodine, Iron,

Aluminum, Bromine, Chromium, Gold, Copper, Lead, Mercury, Silicon, Silver, Tin, Nickel, Platinum and Zinc. Add, because of recent discovery or recently-discovered usefulness, Radium, Thorium, Uranium, Cerium, Tantalum, Tungsten, Vanadium. Potassium, Sodium and Calcium were not isolated (by Davy) until the nineteenth century — Radium (by Curie) till the twentieth.

These make thirty-three—not half your total.

A second list should include Antimony, Arsenic, Barium, Bismuth, Cadmium, Cobalt, Fluorine, Gallium, Magnesium, Manganese, Strontium. Because of the advances in incandescent lighting, we should also add Osmium, Zirconium, Praseodymium.

This list makes only eighteen more.

Yes. Here, alphabetically, is a further and extensive list, for less frequent reference: Actinium, Argon, Asterium, Aurorium, Cæsium, Coronium, Didymium, Erbium, Europium, Gadolinium, Germanium, Glucinum, Helium, Holmium, Indium, Iridium, Krypton, Lanthanum, Metargon, Molybdenum, Monium, Nebulum, Neodymium, Neon, Palladium, Polonium, Rhodium, Rubidium, Ruthenium, Samarium, Scandium, Selenium, Tellurium, Terbium, Thallium, Thulium, Titanium, Xenon, Ytterbium, Yttrium.

Are any of these Elements stable and everlasting?

No; probably not—probably all things change. Dr. Roentgen's X-Ray in 1895 upset previous theories. Hydrogen may make Helium and Neon; Radium may make Helium. All the other radio-active Elements—like Thorium, Polonium, Actinium—may give off Emanations, not yet considered conventionally stable, or named as new Elements. (See Advance of Science.)

Do the Endings of these words signify any Particular Thing?

No, except that by far the greater number of recently discovered Elements have been named so as to end in *ium*, or *um*. *Gen* means to generate; as Oxygen generates acids, Hydrogen generates water, Nitrogen makes nitre, and the four halogens (Chlorine, Bromine, Iodine, Fluorine) generate salt. (See Salt.)

How many Elements appear naturally as gases?

The four leading ones are Hydrogen, Oxygen, Nitrogen and Chlorine. (See note at page 223.)

How many appear naturally as liquids?

Mercury, Bromine, and Cæsium, and also Gallium, probably. All the rest are solids or gases. That is, generally, the

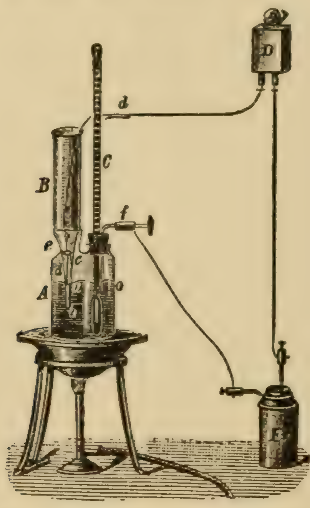


Fig. 80. CHRISTOMANN'S APPARATUS FOR DISCOVERING THE MELTING-POINT, WITH ELECTRIC SIGNAL.

Elements must be heated, as we say, more or less to turn them into fluids.

Give me an idea of the use to which the Elements are put in nature?

The Air consists mainly of Oxygen and Nitrogen, and this envelope surrounds the earth to a great distance. The Water is mainly Hydrogen and Oxygen. The solid earth is mainly Oxygen, Silicon, Carbon, Calcium, Magnesium, Aluminium, Iron and Potassium—that is, far greater quantities of these than of any other Elements could be contracted for, to be delivered on another world. They would be found in quartz, silica, limestone, clay and felspar.

What Elements must animals and plants have?

The only absolutely necessary ones appear to be Carbon, Oxygen, Hydrogen, Nitrogen, Sulphur, Phosphorus, Calcium, Iron, Potassium, Sodium, Chlorine, Silicon and Magnesium.

Fig. 82. PROF. JOLLY'S APPARATUS FOR DETERMINING THE SPECIFIC GRAVITY OF MINERALS.

What is the chemical difference between plants and animals?

An animal absorbs Nitrogen products less readily than a plant absorbs them. Plants breathe out Oxygen; animals take it up. Animals breathe out Carbon; plants take it up. The refreshment felt in the woods and fields is probably due to the great supply of Oxygen that is offered to the lungs of animals whose supplies may have been scanty.

How are Elements compared scientifically?

By extending them into gases, weighing them, noting the amount of heat they have taken up, and measuring the volume into which they have expanded. It is also important that the electric condition of the Element should be noted, and it is therefore put between the poles of a battery where it seeks one or the other, accordingly as it is positive or negative. Faraday demonstrated the likeness of what are called chemical and electrical movements, and gave added weight to the Atomic and Molecular theories.

Who set up these theories, and when?

John Dalton, an Englishman, at the beginning of the century, and Professor Avogadro, an Italian, at Turin, a little later. You might interest yourself in determining which one of these men deserves the most honor, as the Atomic

and Molecular theories are perhaps the most ingenious things that man has done on the earth.

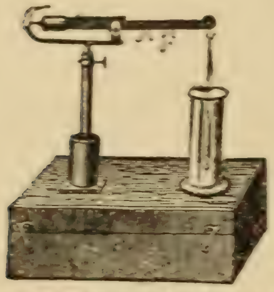


Fig 83. WESTPHAL'S APPARATUS FOR OBTAINING THE SPECIFIC GRAVITY OF LIQUIDS

How did the theories arise?

Certain things had already become evident in Chemistry. If water, air, salt, sugar, or any other compound were taken apart, it was always found to give exact proportions of the Elements that made it. By weighing all the Elements that could be heated into a gaseous form and still weighed, it was determined that Hydrogen was by far the lightest, most of the Elements being from twenty to two hundred times heavier, but all in different degrees. Thus Hydrogen offered a standard of weight at 1, and

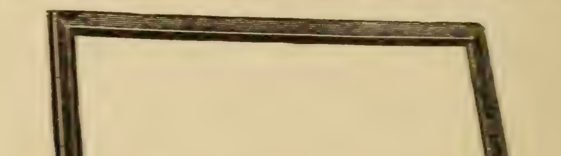


Fig 84. LUX'S BALANCE FOR WEIGHING GASES.

other Elements like Gold, could be put at 196.2 and Iron at 55.9. Let us go farther for the following examples, and weigh Chlorine (a gas) at 35.36 times the weight of Hydrogen, and Silver at 107.66, according to the books. Then we will find that if we mix Chlorine with Silver it will make a new thing, called Chloride of Silver, and if we take the Chloride of Silver apart, we find that out of 143.02 parts of Chloride of Silver. 35.36 were Chlorine and 107.66 were Silver.

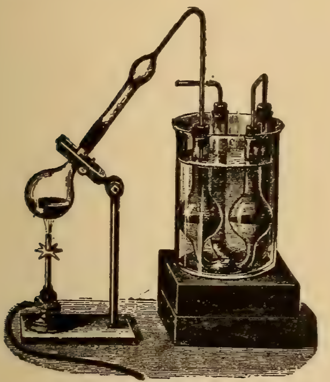


Fig. 85. BUNSEN'S APPARATUS FOR OBTAINING VOLUME OF CHLORINE (gas).

Why do the chemists say ide, in Chloride?

This is a suffix which is specifically added to the non-metallic Elements like Fluorine, Iodine, etc., when they have mixed with some other Element without forming an acid.

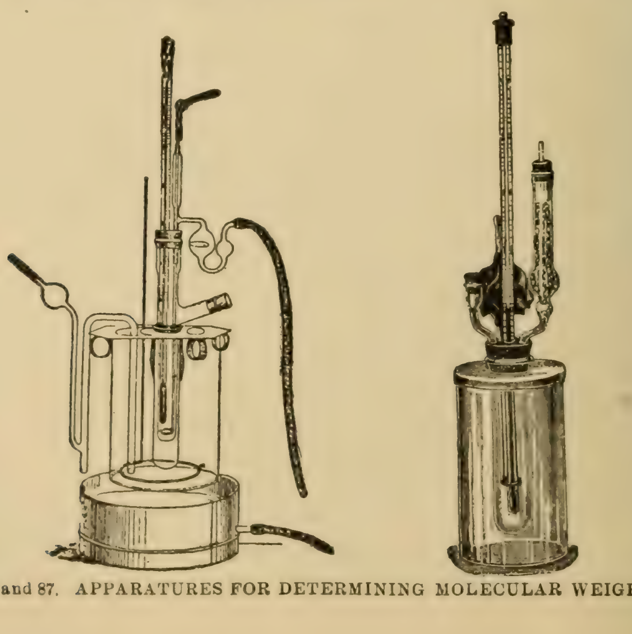
What next did the chemists discover?

They found that certain Elements, like Oxygen, united with other Elements in more than one way, but always in multiple proportions, or regular progression of one, two, three, four or even five times their weight of Hydrogen. Thus, fourteen parts by weight of Nitrogen, united with eight parts of Oxygen. This they called Nitrous Oxide. Twice as many parts of Oxygen (16) united with fourteen parts of Nitrogen and made what they named Nitric Oxide. Thrice as many parts of Oxygen (24) united with fourteen parts of Nitrogen and made what they named Nitrous Anhydride. Four times as many parts of Oxygen (32) united with fourteen parts of Nitrogen and made what they called Nitric Peroxide. Five times as many parts of Oxygen (40) united with fourteen parts of Nitrogen and made what they called Nitric Anhydride. Here were five different substances made out of nearly the same things. It was to be seen that a certain quantity, molecule, atom, or division of Oxygen was

being doubled, tripled, etc. Note also that Nitrogen itself is fourteen times heavier than Hydrogen, the standard.

Did the chemists next experiment with compounds of three Elements?

Yes. They found that when they took compounds of three Elements apart, there was always at least enough of each to make its relative weight once in Hydrogen. If there were more than enough, it was twice enough, thrice enough. For instance, Bromine, an Element, weighs 79.75 parts of Hydrogen. Mix Bromine, Silver and Chlorine together into a new thing; take them apart, and out of the mass there would come 79.75 parts of Bromine, 35.36 parts of Chlorine, and 107.66 parts of Silver. It was found that any two of three such ingredients would themselves combine in the exact way they had clung to or amalgamated with the third. But they might, like Oxygen and Nitrogen, have several ways of uniting, by the doubling, tripling, etc., of one of the Elements. In this way you see, discovery of the relation of Elements rapidly proceeded.



Figs. 86 and 87. APPARATURES FOR DETERMINING MOLECULAR WEIGHT.

What did Dalton and Avogadro do with these laws?

They deduced the theory that the Elements are themselves composed of molecules or combinations of atoms. These atoms have shapes, weights, affinities of their own. They are all alike in their own molecule. But they readily leave their own molecule to attach themselves to a molecule of another kind of atoms; or a whole molecule may attach itself to another molecule; or several molecules may fasten on a larger molecule, making a conglomerate mass; or certain molecules may refuse to fasten to certain other molecules. But usually the molecule of a compound like sugar is composed of atoms from the molecules of the Elements, and these atoms have come together in a new molecule, which to all intents seems as important as the original molecule, and crystallizes into a certain shape, generally different from all other crystals.

How many atoms may a molecule contain?

In order to carry out Avogadro's hypothesis, there are in a molecule of the compound called Albumin, at least 226 atoms, and in Stearin at least 173. Understand, that however impressive the name of a substance may be, if you do not find it in the list of names which have been given on a previous page, it is a compound of two or more Elements, and usually the chemical name will reveal to your ear two of the Elements.

What is this crystal, which I see when I take granulated white sugar in my hand?

Not much is known about it as a crystal. A large company of scientists have striven to reach some hypothesis concerning the crystal. It can be seen springing into existence under the microscope, but why it does so, or in what shapes it may form, is not sufficiently known. Many Elements and compounds are recognized by the shape of their crystals, but the formations are themselves compound, and a crystal may be split down to a smaller shape. Again, Elements (as Sulphur and Carbon) and *compounds*, as Carbon with Calcium, when they crystallize, may make altogether different crystals at different times and in varying conditions. The crystal makes itself, as in sugar, or refuses to make itself, as in molasses. Its molecules in solution throw

light in various ways, and thus give the scientist an opportunity to name substances by this action of their solutions—as the saccharose solution throws light to the right, and is sweeter than the glucose solution that throws light to the left.

You say different molecules can make the same crystals.

Yes. Alum, which is a compound of Sulphur, Potassium and Aluminium, is made of molecules that make the crystal which you see in alum. But molecules of Sulphur, Sodium and Aluminium, or of Sulphur, Potassium and Chromium will make the same kind of crystals. This often leads the chemists to measure the atoms by such means, where they have no better way, it being felt that the atoms are of the same size and shape–that is isomorphous. Vanadium was found through experiments in this direction.

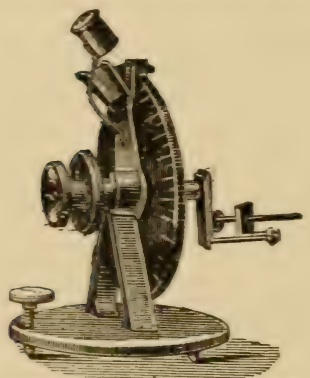


FIG. 88. WOLLASTON'S REFLECTING ANGLE MEASURER FOR CRYSTALS.

Pursue Avogadro's hypothesis a little further.

Avogadro stated, in 1811, that equal volumes of different gases contain equal numbers of molecules. Under the same conditions of pressure, etc., the Elements may be weighed as gases, the amount of heat may be measured which goes into them to make them gaseous, and the pressure may be noted. We now mix Chlorine, a gas, and Hydrogen, a gas. We have found that Chlorine atoms weigh 35.36 times as much as Hydrogen atoms. The mixture is to be called Hydrochloric acid gas. As related to pure Hydrogen, we might expect a mixture weighing 36.36. But in reality, it weighs only 18.18. Now, inasmuch as other experiments with Chlorine have not permitted the existence of an atom weighing 17.68 (or half of 35.36), it would seem that for every atom of Chlorine (35.36) *two* atoms of Hydrogen have been used, and these three atoms have formed one molecule of Hydrochloric acid gas. To prove that the Chlorine atom was not cut in two, (into 17.68),

the chemists take other light or gaseous compounds of Chlorine. Thus, Sulphur Chloride weighs 57.36. On taking it apart, it is found to contain 61.64 per cent. of Chlorine, and this percentage is very close indeed to 35.36 weights of Hydrogen taken in Chlorine. When Oxygen is tested in compounds, it continually shows either 15.96 times the weight of Hydrogen, or multiples of 15.96.

What Elements have been tested and weighed as gaseous compounds?

About thirty, of which Boron, Bromine, Carbon, Chlorine, Hydrogen, Iodine, Lead, Mercury, Nitrogen, Oxygen, Phosphorus, Silicon, Sulphur, Tin and Zinc are the most important.

How did the chemists study the Elements that they could not readily treat in the form of gases?

They attempted to ascertain the Specific Heat. If the Elements be raised in temperature, say from 50 to 55 degrees, a

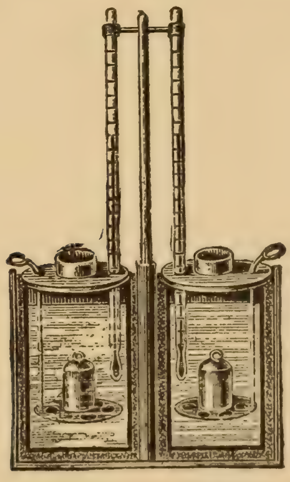


Fig. 89. APPARATUS FOR COMPARING THE SPECIFIC HEAT OF ANY TWO BODIES.

different amount of heat will be required for each one, and if they be lowered ten degrees, each one will give off a different amount of heat. For a standard, one gramme of water is raised

from a temperature of 0 to 1 degree Centigrade in Paris. This would be a heat-unit.

Define these terms?

A gramme is a French unit of weight. A cubic centimetre of water at 39.2 degrees Fahrenheit at Paris, in a vacuum, weighs 15.433 grains avoirdupois. A Centigrade thermometer has zero at the freezing point (32 degrees Fahrenheit), and the space to the boiling point (212 degrees Fahrenheit), is divided into one hundred places or degrees.

What was found by Specific Heat?

The Elements usually absorbed or gave off a number of heat units which could be divided 6.3 times in order to get the figure representing the weight of the atom, according to Avogadro's hypothesis. The scientists then adopted a theory of atomic weights for such of the Elements as they could not weigh in gaseous forms, and they did it by means of the Specific Heat. They also studied the crystals.

What are these Elements so treated?

The most important are Aluminium, Calcium, Copper, Gold, Iron, Magnesium, Manganese, Nickel, Platinum, Potassium, Silver and Sodium.

What is agreed upon as to the molecules of Elements?

Thirteen Elements have been theoretically and experimentally developed with regard to a molecular hypothesis. Beginning with the belief that a Hydrogen molecule contained two atoms, the same condition is now scientifically suggested for Chlorine, Bromine, Iodine, Nitrogen, Oxygen, Selenium and Tellurium. Mercury and Cadmium appear to have only one atom in their molecules. Sulphur, at different very high temperatures, has six and two atoms respectively. The greater heat, the fewer the atoms in the Sulphur molecule.

What are Symbols?

These are the letters which stand for the Elements. These letters usually furnish a clew to the word they represent. Sometimes, however, a foreign language has been used to name the Element. These exceptions are Sb (Stibium) for Antimony;

Au for Gold (Aurum); Fe for Iron (Ferrum); Pb for Lead (Plumbum); Hg for Mercury (Hydrargyrum); K for Potassium (Kalium); Ag for Silver (Argentum); Na for Sodium (Natrium); Sn for Tin (Stannum); Cu for Copper (Cuprum); and W for Tungsten (Wolfram). Barring these eleven Elements, the others begin with letters that agree with their English names, but only a few are represented by a single letter. In Mendeléef's table, at page 547, the Symbols and conventional atomic weights of Elements in Hydrogen atoms may be studied.

What Elements are represented by the single capital letters with which their names begin?

Boron, Carbon, Fluorine, Glucinum, Hydrogen, Iodine, Nitrogen, Oxygen, Phosphorus, Sulphur, Uranium, Vanadium, Yttrium. No Element is represented by two capital letters. Some of the letters, such as A, D, E, J, M, Q, R, T, and Z, are not utilized separately for Elements. Small letters are added to particularize, as in the four B's—Barium, Ba; Bismuth, Bi; Boron, B; Bromine, Br. Some of the most important *compounds* have Symbols, notably MCy for Metallic Cyanide, but this is rare.

Why are Symbols used?

To give an instantaneous knowledge of the chemist's theory of the constitution of his compounds. Thus, he writes Sulphuric Acid—H_2SO_4. This is to inform us that he holds that each molecule of this substance is formed of two atoms of Hydrogen, one atom of Sulphur, and four atoms of Oxygen. So far as they can, chemists hope to express a single atom by a single Symbol like S in the Sulphuric Acid Symbol, and the number of atoms in a molecule by the small figures; but this they do not always accomplish. It is perfectly safe for you to read a chemical Symbol like $C_2H_4O_2$ (Acetic Acid) as two atoms of Carbon, four atoms of Hydrogen, and two atoms of Oxygen. This combination of Symbols, or any other, is called a *formula*. A large figure put in *front* of the formula multiplies the entire formula—thus, $2C_2H_2O_2$ is equal to the formula $C_4H_4O_4$.

What is a Chemical Equation?

It is a rapid statement of what follows a mixture of Elements

How many Elements appear naturally as gases?

The four leading ones are Hydrogen, Oxygen, Nitrogen and Chlorine. (See note at page 223.)

How many appear naturally as liquids?

Mercury, Bromine, and Cæsium, and also Gallium, probably. All the rest are solids or gases. That is, generally, the

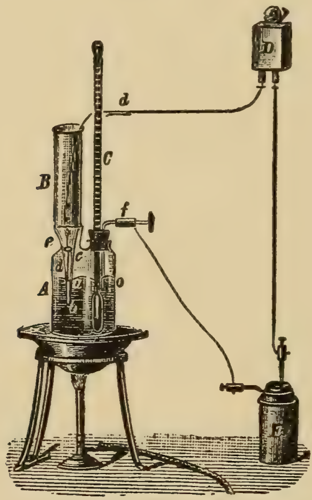


Fig. 80. CHRISTOMANN'S APPARATUS FOR DISCOVERING THE MELTING-POINT, WITH ELECTRIC SIGNAL.

Elements must be heated, as we say, more or less to turn them into fluids.

Give me an idea of the use to which the Elements are put in nature?

The Air consists mainly of Oxygen and Nitrogen, and this envelope surrounds the earth to a great distance. The Water is mainly Hydrogen and Oxygen. The solid earth is mainly Oxygen, Silicon, Carbon, Calcium, Magnesium, Aluminium, Iron and Potassium—that is, far greater quantities of these than of any other Elements could be contracted for, to be delivered on another world. They would be found in quartz, silica, limestone, clay and felspar.

What Elements must animals and plants have?

The only absolutely necessary ones appear to be Carbon, Oxygen, Hydrogen, Nitrogen, Sulphur, Phosphorus, Calcium, Iron, Potassium, Sodium, Chlorine, Silicon and Magnesium.

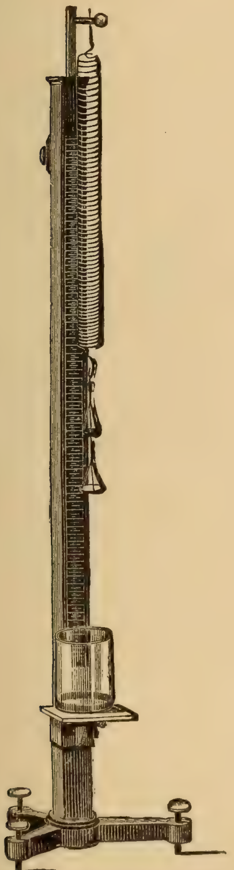


Fig. 82. PROF. JOLLY'S APPARATUS FOR DETERMINING THE SPECIFIC GRAVITY OF MINERALS.

What is the chemical difference between plants and animals?

An animal absorbs Nitrogen products less readily than a plant absorbs them. Plants breathe out Oxygen; animals take it up. Animals breathe out Carbon; plants take it up. The refreshment felt in the woods and fields is probably due to the great supply of Oxygen that is offered to the lungs of animals whose supplies may have been scanty.

How are Elements compared scientifically?

By extending them into gases, weighing them, noting the amount of heat they have taken up, and measuring the volume into which they have expanded. It is also important that the electric condition of the Element should be noted, and it is therefore put between the poles of a battery where it seeks one or the other, accordingly as it is positive or negative. Faraday demonstrated the likeness of what are called chemical and electrical movements, and gave added weight to the Atomic and Molecular theories.

Who set up these theories, and when?

John Dalton, an Englishman, at the beginning of the century, and Professor Avogadro, an Italian, at Turin, a little later. You might interest yourself in determining which one of these men deserves the most honor, as the Atomic

gen, Oxygen and other Elements, in which the study abounded. Then there are the Hydrides, the Oxides, the Acids, the Salts and the Sulphides. There is a group of Chlorides, Bromides, Iodides and Fluorides—the salt-makers. Nitrogen is an exclusive Element, and makes but few alliances, so that the Nitrides are not numerous, but the Ammonias and the Cyanides (themselves from Nitrogen) are the parents of vast groups of compounds. The Phosphites, the Alkalis, the Iron group, the other metallic groups, complete the necessary parts of a passing index of Chemistry.

Explain words like Sulphide, Sulphate, Sulphite, etc.

Where bodies unite in only one simple way, like Chlorine and Sodium (making salt), it is easy to name them, but bodies with the Valency of Oxygen, Sulphur, Phosphorus, Chlorine, etc., give the scientists more trouble. You may usually consider *ide* to be the broadest term, and Sulphide and Sulphuret are the same, meaning a mixture of Sulphur with some other (non-acid) body. *Ic* means that there is more of some element used than if it were *ous*—thus Sulphuric Acid has more atoms of Oxygen than Sulphurous Acid. Sulphite is a union of Sulphurous Acid with another Element. Sulphate is a union of Sulphuric Acid with another Element. As we have many Elements, the number of formulas possible is not to be limited, and chemists are likely to attempt to give a descriptive name to each of the most interesting combinations of Elements. These names, of course, must test the entire capacity of our language. It is much easier to learn the Symbols and then read the formulas by that means. But the suffix *ium*, or *um* for the newly-discovered Elements, *ite* for rocks, and the other suffixes that we have noted, with Sulphur (or some other Element) as a mere stem on which to place them, will give you a reasonable understanding of the chemical terms that we hear most frequently.

I did not know Carbon was so important. What is this Element?

It is always present in all animal or vegetable substances. While it seems probable that only a small number of atoms of other Elements combine in compound molecules, there is only a

very high limit to be placed on the number of Carbon atoms that may so unite. While the other Elements will furnish one stable compound each with Hydrogen, Carbon will unite with Hydrogen in hundreds of ways. Nor are these the only perplexing features of Carbon. It is also Allotropic.

What does Allotropic mean?

It means different appearances for the same thing. You may see a diamond. It may have any color. It is Carbon in its crystallized form. You may also see the black substance in your lead pencil, called graphite. That also is Carbon, in its crystallized form. Again, in lamp-black you may see Carbon in an extremely soft powder, without form. In diamonds the crystals are eight-sided, or related to eight-sided forms, and very hard—the hardest substance known ; in graphite the crystals are six-sided and soft ; in lamp-black and other coals, cokes, etc., there is no regular form to the grains. It would require over 14,000 degrees of heat Fahrenheit to make a diamond boil; the greatest heats usually practicable char it into formless charcoal. It is but logical that the chemists should hold that the diamond is the really pure form, and that the two other forms are impure. But Oxygen and Ozone offer a similar puzzle of Allotropy, being different things to all intents and purposes, but made of the same Element.

Have diamonds been made?

In 1896, before the New York College of Physicians and Surgeons, M. Henri Moissan, of the Institute of France, gave his demonstration of the methods by which diamonds are produced in nature. He determined that the Carbon is subjected to great pressure. To get this pressure, he chose Iron. When fluid Iron grows cold it shrinks. By making a little bullet of Iron, with charcoal inside, he obtains a tiny diamond. The apparatus is a brick crucible—two thick bricks with a small cavity between them. Into this cavity the crucible is placed. The cavity is sprinkled with magnesia. Into the little crucible he puts Iron filings and charcoal. The bricks are put together. Then, with Electricity he heats the crucible to a temperature of 3,500 de-

grees. In the region of the crucible there is a boiling and flaming of clay and Iron. In ten minutes the process is complete. The crucible is dropped in cold water. The Iron bullet

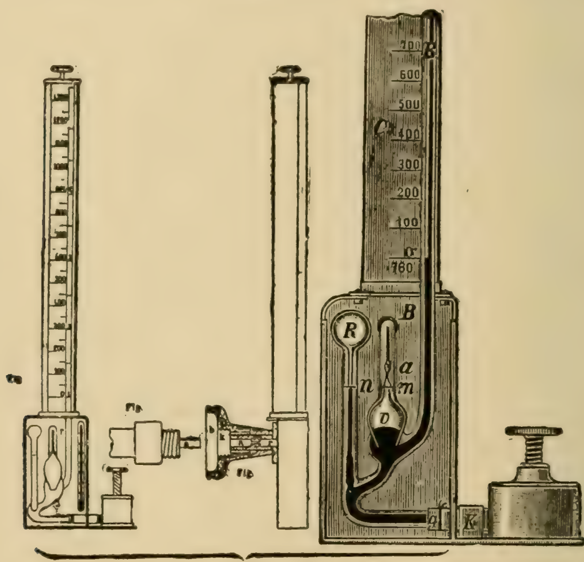


Fig. 90. THERMOMETER, MEASURING AS HIGH AS 2,700 DEGREES ABOVE ZERO, FAHRENHEIT.

in the crucible now condenses as it cools, pressing the charcoal into diamond. The diamond made is small, faulty and comparatively worthless, but it is diamond. M. Moissan finds that the manner of cooling determines the color of his diamond product. On the Allotropic nature of Carbon he has learned that Carbon becomes a gas and reacts into graphite unless it be under pressure, when it only liquifies and returns to solid as a diamond.

Have formulas been made for all common things?

No. As the commonest and yet the most remarkable things are Carbon compounds, there the chemists have found their most difficult problems. They do not yet attempt to write the formulas for the tree-gums—the resins, mucilage, gum traga-

canth, India-rubber, balsams,—the bitumens, the albuminous substances, such as the whites of eggs, the globulin in our blood, the casein in cheese, pepsin in our stomachs, and many other

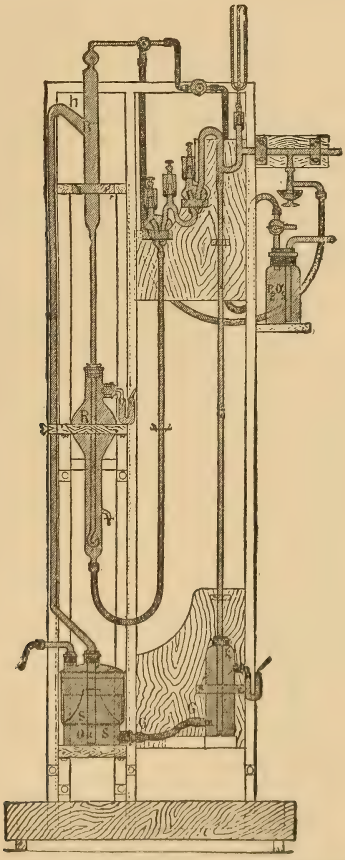


Fig. 91 AUTOMATIC LOW-PRESSURE AIR PUMP FOR THE DISTILLATION OF UNSTABLE SUBSTANCES IN THE HYDRO-CARBONS.

compounds, all of them extremely familiar. That is, no chemist attempts to say *how* the molecules of these substances come together, although the Elements concerned are usually Hydrogen, Nitrogen, Carbon, Oxygen and sometimes Sulphur, as Carbon in the Albuminoids.

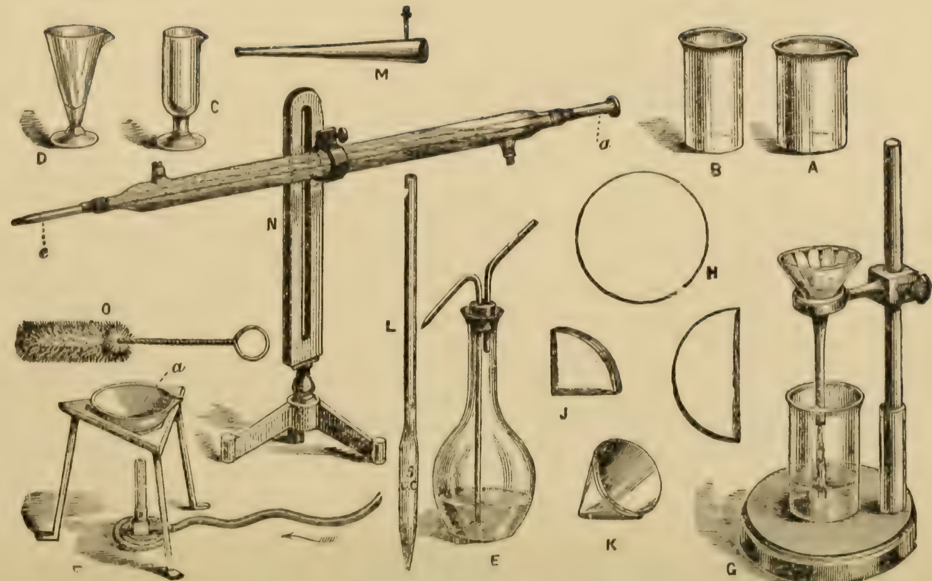


Fig. 92. APPARATUS USED BY CHEMISTS.

A, B, Beakers; C, D, Test glasses; E, Wash bottle; F, Evaporation, showing evaporating dish (*a*) supported by an iron tripod, and Bunsen burner; G, Filtration; H, I J, K, Method of folding filter paper; L, Pipette; M, Black's blow pipe; N, Liebig's condenser; O, Test tube cleaner.

Why are the glass tubes of the laboratory so full of bulbs?

The bulb offers more surface, on which the vapors (or gases) that rise in the tube may precipitate and turn to liquid.

Name some of the Carbon groups that are fully theorized.

The Hydro-Carbons are the parent forms of all the Carbon compounds that are to follow, and they are themselves divided into many series, say fifteen in number. India-Rubber is a pure Hydro-Carbon. There is the marsh-gas (Methane) or Paraffin series; the Olefine or oily series; the Acetylene series; the Terpene series (the essential feature of Turpentine, Lemons, Oranges, etc); the Benzene series of Benzene, Naphthalene, Anthracene, etc., in which theory carries the molecule to a ring of Carbon atoms with arms of Hydrogen atoms (Benzine), or two circles of Carbon atoms in a large ring of Hydrogen atoms (Naphthalene), or even still more complex forms. The Benzenes and Naphthalenes are themselves divided into many series. All these Hydro-Carbons are used by nature to make the other and following groups in Organic Chemistry.

Name some of the Carbon groups that have their descent from a union with Hydro-Carbon molecules.

First in popular interest are the Alcohols, of which there are

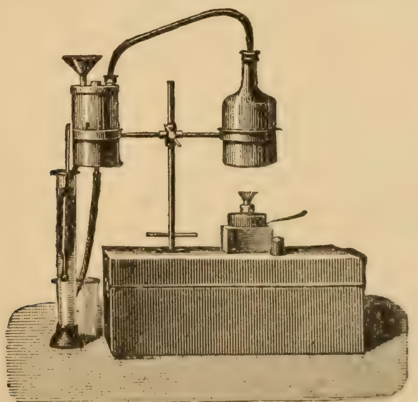


Fig. 93. APPARATUS TO FIND THE QUANTITY OF ALCOHOL IN BEVERAGES, ETC.

many families. An Alcohol is usually fluid, but may be a crystalline solid. It is often an oil. It is often made by the action

of an atom of Oxygen and an atom of Hydrogen, acting together in one molecule as an acid Radicle—that is .OH, or Hydroxyl—on another molecule of Hydrogen and Carbon. The Alcohol we buy at the drug-store is a union of two atoms of Carbon, five atoms of Hydrogen, with the outside Radicle molecule of one atom each of Oxygen and Hydrogen. There is a huge number of Oxygen Alcohols, and as Sulphur, Selenium and Tellurium will form Radicles with Hydrogen, there may be three more families—Sulphur, Selenium and Tellurium Alcohols. Sugar, as we said, is classed as a Polyvalent Alcohol.

What are Ethers?

A second great group. They are derived from all four of the families of Alcohols, and also from the four Halogens or salt-makers—Chlorine, Bromine, Fluorine and Iodine. The very common and well-known "Sulphuric Ether" or "Sulphate of Ether" has not an atom of Sulphur in it, viz., $(C_2H_5)_2O$.

What are Aldehydes?

A third great group, made from at least eleven of the primary Alcohols, and to be made from all. Two atoms of Hydrogen are withdrawn from the main or stem-molecule of Alcohol, leaving the Radicle molecule still clinging. It is an Aldehyde that gives the aroma to Cinnamon, Cassia, Benzoin and other odorous things.

What are the Ketones?

A third great group, called after the Greek name for Whale. They are made from the Aldehydes, with certain changes in the subsidiary molecules or Radicles. With one of the Ketones, Methyl-Phenyl-Ketone, by the action of Nitric Acid, Soda-Lime and Zinc-dust, the chemists make Indigo-blue (Aniline).

What are the Organic Acids?

A fourth great group, in which is Vinegar, or Acetic Acid. We have shown, in a previous chapter, how Vinegar is made from common Alcohol. Each of the Organic Acids may be made from some one of the Alcohols. Two atoms of Hydrogen are taken away and one atom of Oxygen joins the new molecule.

What are the Anhydrides and Acid Halides?

A fifth great group, related to the Organic Acids as Ethers are to Alcohols. All Oxygen acids were first known as Anhydrides. Anhydrides are the Ethers of Acid Radicles. An Anhydride is often a heated Organic Acid. Add water to an Anhydride and it becomes an Organic Acid. The Acid Halides are the Organic Acids in which atoms of the Halogens or salt-producers, that is, Bromine, Chlorine, Fluorine and Iodine, are concerned.

What are the Ethereal Salts?

A sixth great group of the Carbon Compounds. Any acid, Organic or Inorganic, Carbon or non-Carbon, may combine with Alcohols so as to form Ethereal Salts. Ethereal Salts may be normal or acid. Many Acids form Ethereal Salts by seeking the little sub-molecule that attaches to the Alcohol molecule. The theory of the Ethereal Salt molecule represents it as very complex, although only three Elements enter into it. Their atoms form rings, or squares, or cubes with certain atoms as centres, or certain layers. Nature forms the greater number of these Ethereal Salts.

Name some Ethereal Salts that are well known.

The oil of wintergreen owes its fragrance to a four-layered molecule which makes Methyl-Salicylate. The Oleins, Palmitins and Stearins are all Ethereal Salts of Glycerin. You will best understand what Glycerin is by remembering the old name of Glucose—that is, Glycose, and you know what Glucose is. (See Sugar.) Glycerine is a highly important chemical. The Glucosides are Ethereal Salts, and they are contained in many of the vegetable coloring-matters, like Madder. What we know as Vanilla is a Glucoside, or Ethereal Salt.

What are Organo-Metallic Bodies?

A seventh group of the Carbons that descend from the Hydro-Carbons. There are twenty-nine of these bodies known. They are not merely Organic or Carbon compounds that contain mineral Elements, but the Hydro-Carbon sub-molecule or Radicle must directly hold the metal atom, and not be connected merely by a chain of other atoms. The molecule of Zinc Ethide,

an example of Organo-Metallic bodies, is theorized as a row of four molecules, made of ten atoms. The last molecule is a Hydro-Carbon Radicle or molecule, and it touches the Zinc atom. Touching this chain of four molecules, but not touching the Zinc atom, are two other molecules of two atoms each of Hydrogen. These Organo-Metallic bodies serve as tools with which the chemists seek new or old results with other Elements, and are very useful.

What are the Amines?

An eighth group, highly important in a popular sense, because they contain the celebrated Aniline. The Amines are all deri-

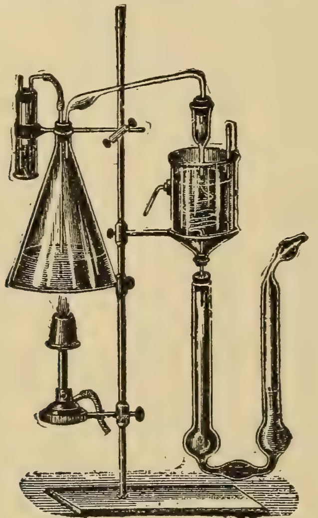


Fig. 93½. APPARATUS FOR DETERMINING THE AMMONIA IN PLANTS AND VEGETABLE EXTRACTS.

vations of Ammonia, which we will speak of when we reach the Element Nitrogen. The names of these salts usually end with *amine.*

I am particularly desirous of knowing what Aniline is.

It takes its name from the Indigo-plant, which is called by the botanists *Indigofera Anil.* Its chemical name is Phenylamine. If we take its name to pieces we shall find *phene,* coal-tar, *yl,* an

acid Radicle or sub-molecule, and *amine*, a derivative of Ammonia. Aniline was first distilled from Indigo by the agency of a Potassium compound. It is found in coal tar oils. It is manufactured on a large scale for dye-stuffs by reducing Nitro-benzine with Iron and Vinegar, and has replaced all vegetable colors.

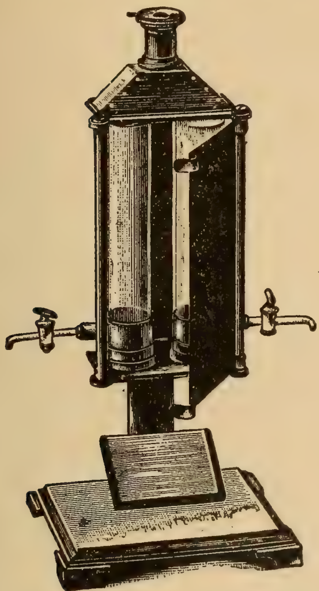


Fig. 94. WOULFF'S COLORIMETER, FOR INSPECTING ANILINE DYES.

How does Aniline look?

It is a colorless, oily liquid, having a peculiar odor. Millions of dollars worth of this substance or its compounds are imported each year into the United States. It is united with other compounds to make all the colors with which we are acquainted. These dyes may be used for all the cloths, leathers, papers, inks, candies, celluloids, horn-goods, ivories, etc.

What is Aniline Red?

It comes in the form of Rosaniline Salts, a compound of Aniline and Toluidine (certain molecules of Carbon, Hydrogen and Nitrogen). It is the most important of all these multitudinous dyes. It makes magnificent green crystals, soluble in water, with a color varying from a beautiful cherry-red to a crimson. The number of possible Aniline Reds is beyond computation. Saffranine is an Aniline Pink, or Aniline Oxide.

Are there Aniline Violets and Blues?

Vast numbers of them. In the name of one—Ethyliodate of Triethylrosaniline—you may take apart the compounds (of Ether, acid Radicle, Iodine and third Ether, acid Radicle, red Aniline) of which one Blue color is made. It is theorized as containing a chain of nine molecules of Carbon, Hydrogen, Nitrogen and Iodine, sixty-one atoms in all, disposed in a com-

plex manner. The Blues are catalogued as Mauves, Hoffman's Violets and Blues, Phenyl-Rosanilines, Tolyl-Rosanilines and a great class of secret Blue colors.

What are the Aniline Greens?

They are classed as the Aldehyde Greens, the Iodide Greens, Iodide of Ethyl Greens and Potassic Chlorate of Ethyl Greens. The wonderful Aldehyde Green was discovered by accident, Cherpin, the chemist, being in search of a good Blue. This Green is chosen for silks.

Notice the other colors.

Aniline Yellows are little used in dyeing or printing cloths. The celebrated Picric Acid is used. There are several Browns and Maroons. The best Grays are still too costly. Good Blacks are not yet secured, but cotton, silk or wool, may be colored to a shade closely approaching black. In silk and wool dyeing, no mordant is needed. The largest manufactories of these wonderful combinations of molecules are in Germany.

What is an Amine—such as you have named?

It is a salt produced by the substitution in Ammonia of non-acid Radicles, or sub-molecules, for Hydrogen atoms—the latter are taken out. The Amines are called Compound Ammonias. When the Radicle is acid (*yl*) the Amine becomes an Amide.

What are the Amides?

They are, as you see, related to the Amines as the Aldehydes are related to the Alcohols and the Anhydrides to the Organic Acids. They are the ninth and last group that we must notice of the great phalanx of Organic or Carbon Compounds.

Define the term Organic Chemistry.

If, in the taking apart of a compound, certain molecules come away together, it is held that they are not a necessary part of the larger molecule to which they clung. That larger molecule must have been organic. That is, made up of groups of atoms rather than of atoms. Thus, although Acetic Acid (of which Vinegar is a diluted state) is made of four atoms of Hydrogen, two atoms of Carbon, and two atoms of Oxygen, but one of its atoms of Hydrogen will come away and give place to an atom

of metal: Again, one of the Oxygen atoms will come away with a Chlorine atom. Thus there is left a union of two atoms of Carbon, three atoms of Hydrogen and one atom of Oxygen as the inner or stable molecule. This molecule, C_2H_3O, is therefore called Acetyl—that is, it is the sour Radicle of Acetic Acid, and the Acid itself is theorized as a chain of one Hydrogen, one Oxygen, clinging to that Radicle, C_2H_3O. This is Organic or Structural Chemistry. Liebig was its great teacher.

What is its leading characteristic, more specifically described?

Organic Chemistry is the science of Compound Radicles, and is largely made up of treatment of Radicles made of Hydrogen and Carbon.

What is the great exception?

Cyanogen, a colorless gas composed of Nitrogen and Carbon, called Cyanogen, because it *makes blue*, discovered by Gay Lussac, of Paris, in 1815. He isolated the substance, and thereby found the first compound Radicle. This extremely poisonous molecule of Carbon and Nitrogen has a sign of its own —Cy—and unites so greedily with the metals that the metallic Cyanides also have a sign—MCy.

For what is Cyanogen most notable?

For its uses in extracting gold from its ores and other surroundings. The Metallic Cyanides of Iron and Potassium are very important. Cyanogen and its compounds form a link between Organic and Inorganic Chemistry.

Proceed to the other great branch of Chemistry.

Of course, there is no other branch of Chemistry after the whole history of Carbon has been given, but the mind conveniently divides the subject at the point where substances are to be studied without reference to Carbon or to Hydro-Carbons, or to Hydroxlys—that is, as we have shown, Hydrogen and Oxygen in a sour Radicle.

What is Nitrogen?

Nitrogen is a colorless, odorless, tasteless, incondensable gas, that constitutes four-fifths of the air we breathe. Air is not a compound of Nitrogen and Oxygen, but a mixture, like salt and

pepper mixed. Nitrogen is necessary to all animal and vegetable tissues. It therefore becomes one of the most useful commercial products, yet for ages it was necessary to obtain it or its useful compounds rather from the outworn processes of Life than from the free air in which it was the chief Element. With the cheapening of Calcium, however, the "artificial" Nitrates entered the commercial and agricultural worlds. The moderns will not starve as the ancients did.

Fig. 95. A NITROGEN BULB.

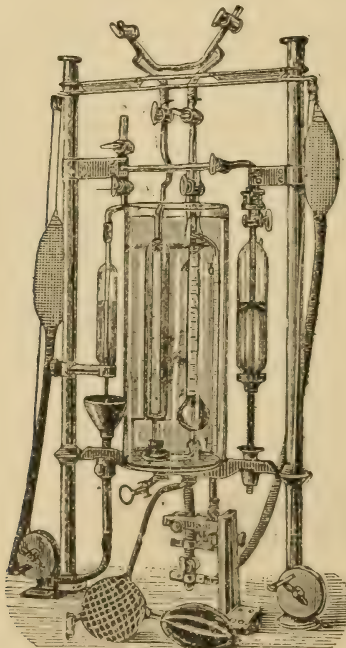


Fig. 96. APPARATUS FOR QUICK ANALYSIS OF AIR, ETC.

What is Nitro-glycerin?

It is the fluid which is soaked into sticks of earth and called

dynamite, or other blasting preparations of the kind. It is a Carbon-Oxygen-Hydrogen compound, into whose molecule a Radicle molecule of Nitrogen-Oxygen has been introduced. It is made by dropping glycerin into very cold Sulphuric and Nitric Acids mixed. The mixture is put into water, and the Nitro-glycerin settles. It is the most effective blasting preparation in general use. Nobel, who invented the means of using it, died at San Remo, Italy, in December, 1896.

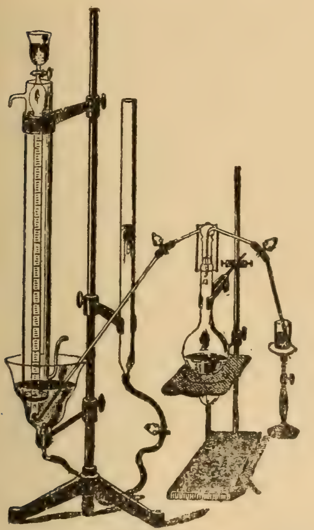


Fig. 97. SCHELLBACH'S APPARATUS FOR MEASURING NITROGEN IN GUN COTTON AND OTHER EXPLOSIVES.

What is Ammonia?

It is a pungent gas, the Nitride of Hydrogen. We see it as Aqua Ammoniæ, and we smell it in many decomposing substances. It was named at the Temple of Jupiter Ammon, in Libya, where it was made in the camel stables, ages ago, when the god Amen was the deity of the chief city of Egypt.

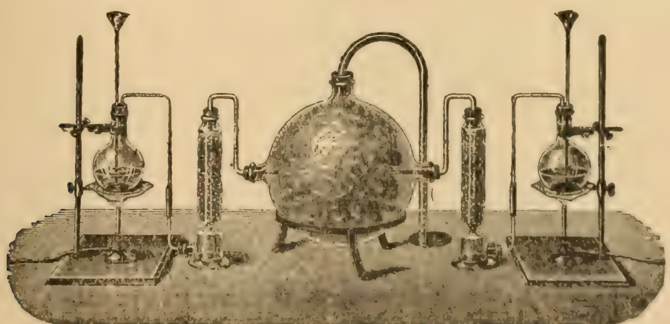


Fig. 98. APPARATUS FOR THE MANUFACTURE OF AMMONIA.

For what is Ammonia celebrated in Chemistry, aside from its value as a fertilizer?

It is the base of the Amines, which we have described. In the Ammonia, one atom of Nitrogen remains stable while the three atoms of Hydrogen are variously played upon by Hydro-Carbon Radicles. In the great Aniline group, the base was a double molecule of Ammonia, toward which a molecule of six Carbons and one Hydrogen approached, whereupon two of the Hydrogens in the Ammonia left their own molecule and saturated into the new comer, and all thirteen of the atoms, thus organized, became one molecule which would now act as a base for all the dyestuffs.

How are the Nitrates of Commerce prepared?

By the boiling of animal tissues, the waste of the slaughter-houses. The product is dried like malt, and sold by the ton. It was deplored by the scientists that the fertility of the United

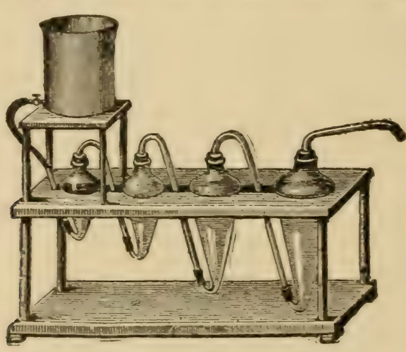


Fig. 99. APPARATUS FOR ANALYZING THE SOIL.

States was slowly but surely being sapped by the cities. But during the early decades of the twentieth century the most surprising advances (through electricity and the knowledge of bacteria) were made in the "fixation of Nitrogen."

What is Oxygen?

The most important of the Elements in a physical sense, because it is the most abundant. It is the chief part, by weight, in water. It is a fifth of the air. It unites with all the other

Elements, but never in more than five ways. It was first isolated by Priestly, in 1774. It was called Oxygen, *sour-maker*, because it was then believed that all acids must have Oxygen.

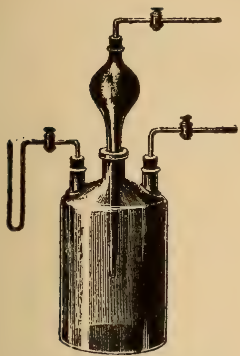


Fig. 100. WOULFF'S BOTTLE, FOR MAKING OXYGEN.

What is Ozone?

Under the action of Electricity, Oxygen contracts in volume, and its molecules, instead of holding two atoms, as in a natural state, hold three atoms. This substance is Ozone, which has an unpleasant smell, and may be noted in the open air after a thunder shower. Ozone has, at times, been regarded with favor as a health-giving gas. But pure Ozone has never been isolated.

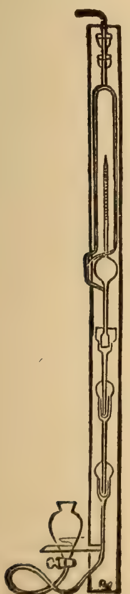


Fig. 101. M'LEOD'S AIR GAUGE, FOR MEASURING PRESSURE DOWN to ONE TEN MILLIONTH OF ATMOSPHERE.

What is Water?

It is a union of two parts of Hydrogen and one part of Oxygen. These are highly expanded gases, while Water is a very substantial liquid. When the two gases are brought together at an ordinary temperature, they do not unite, but the introduction of great sudden heat will cause them to unite with explosion, and the "ashes" will be water—of course, only a little water, considering the great bulk of the gases that made the Water. When the Water is heated into gas, it has only two-thirds the volume of the previous mixture of two gases. It was at first believed that Water was eight parts Hydrogen and one part Oxygen.

For what is Water remarkable?

It is a neutral compound, and yet there are few substances that are not dissolved by it. It is easily boiled, and expands into sixteen hundred volumes as steam. Under pressure, the boiling-

point is reached at a higher mark than 212 degrees, and its generally mysterious action when enclosed in heated vessels has been the cause of many terrible accidents. Water will absorb more heat than any other substance save Hydrogen, and therefore furnishes the standard of heat-units. When a substance will not dissolve in water, it is tasteless. It expands as it gets cold, then contracts, then expands, as ice. It is a pale blue in color. The abundance of Water, and its usefulness in the laboratory, have perhaps made Chemistry as an advanced science possible.

Is all Water alike?

Yes. Water from any spring, from the ocean, or from the most distant part of the earth may be cleared of its impurities, and readily furnishes the chemist or the druggist with *aqua pura* —pure water in molecules of H_2O. The ocean is the prime

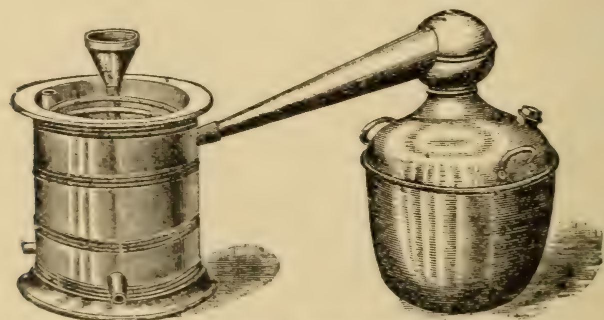


Fig. 102. A DISTILLERY FOR WATER.

source. Vapor is constantly rising and the vapor is precipitated over the earth. Eight-elevenths of the Water returns to the ocean through rivers. It has a chemical sign beside H_2O. It is Aq.

What is Hydrogen?

Hydrogen is a gas. It is the lightest of the Elements, and therefore the standard of their weight. It is named Hydrogen, the Water-maker. When Cavendish discovered and isolated it, in 1776, he called it Inflammable Air. It burns in the free state in volcanoes, in the Sun, the Stars and the Nebulæ. It is the

base of all acids—that is, all acids are salts of Hydrogen, but all acids are desirous to give up their Hydrogen for a metal. We

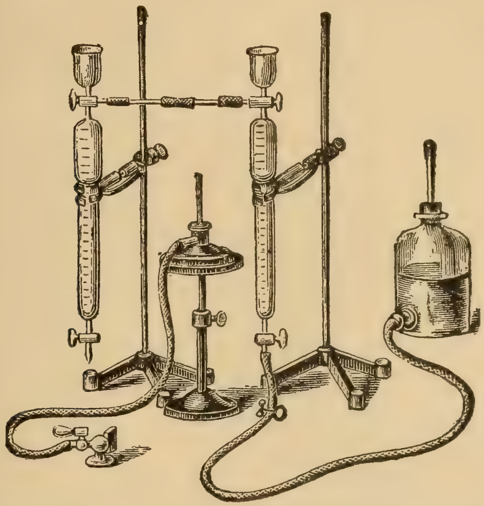


Fig. 103. APPARATUS FOR MEASURING VOLUME OF HYDROGEN.

say it is the base of *all acids*, but we are without an acid with which to make the first salt—the beginning of the system. The acids are innumerable, and there are atoms of Hydrogen in each of them. Chlorine, Bromine, Iodine, Sulphur, Cyanogen (NH), Fluorine, and other Elements may take the place of Oxygen, so that Hydrogen has pushed Oxygen out of its place as the "acid-maker." We have already shown the importance of the Hydro-Carbon molecules.

What are the Halogens?

Chlorine, Fluorine, Bromine and Iodine. (See Salt.) They are the Salt-Producers. Fluorine has not been isolated. Bromine is a red liquid. Iodine is a black, crystalline solid. Chlorine, as we have said, is a green gas. It comes into market in copper cylinders, and under pressure as a liquid. These four Elements are always grouped together, and where a Radicle will cling to the molecules of one of them, it will cling to all. The metallic crystals are alike.

For what is Chlorine famous?

It is in table salt. It is in the Gold compound that has been taken as a specific cure by alcoholic invalids all over the world. It is in Chloroform (Formic acid is from *red ants*), the wonderful anæsthetic or pain-killer. It is used in making gelatine. It

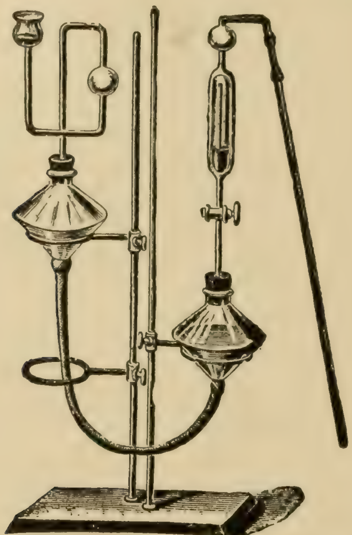


Fig. 104. KAEHLER'S GAS GENERATOR, FOR MAKING CHLORINE.

is in Chlorate of Potash, used in matches. The Chlorides of Silver, Sulphur and Zinc are in daily use. Chloride of Lime is bleaching powder. It is a leading disinfectant. Hydrochloric acid, as now used in the arts, is a bye-product of the alkali manufactories. The gas once escaped in the air and blighted surrounding vegetation, but laws were passed to stop this, with the result of compelling better economies. Our salt, our matches, our clothes, all our paper, our medicines (including Chloral—from Chlorine and Alcohol), some of our foods, and many of our implements and ornaments owe their existence more or less directly to Chlorine. It was isolated by Scheele in 1774.

What of Iodine?

It was named from a Greek word for *violet-colored* because

of the appearance of its vapor. Its chief use commercially is as Methyl-Iodide, in the production of Aniline dyes. The photographers use it with Cadmium, Potassium and Ammonia (NH_3). Iodoform (CHI_3) is one of the most odorous chemicals, outdoing Carbolic acid. The Iodides of Potassium, Iron and other metals are well-known medicines.

What of Bromine?

It is named from *bromos*, "a bad smell." It was discovered in 1826, by Balard. There are twenty-four grains of Bromine to the gallon of ocean-water. It is prepared from the salt-springs of West Virginia and Pennsylvania by the hundreds of thousands of pounds. Its chief use is in medicine as Bromide of Potassium. The Bromides are taken at the drug-stores by people who feel "nervous," and with Chloral, have done much to destroy health through unscientific use. Physicians should always be consulted.

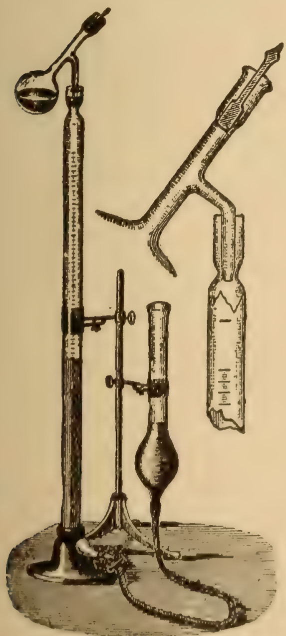


Fig. 105. MACHINE FOR MEASURING VOLUME OF THE ELEMENT FLUORINE.

Is Fluorine abundant?

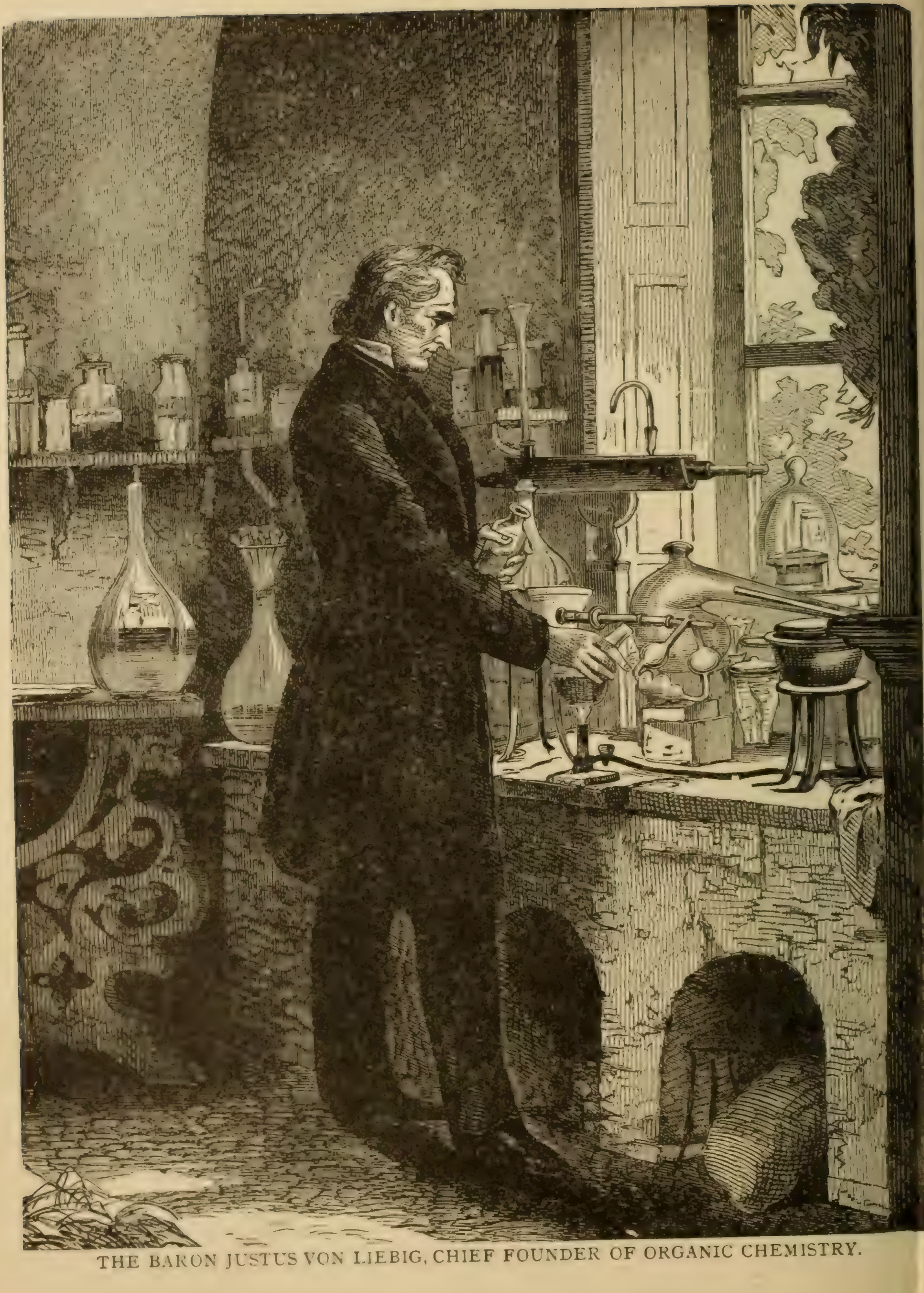
It is widely diffused, but in small quantities. It exists in sea-water, always in teeth and bones—more in fossil bones than those of present formation. It will corrode any vessel in which it is gathered, and even glass cannot be used. It is related to Oxygen as well as to Chlorine by its effect on other Elements.

What is the Sulphur group?

Sulphur, Selenium and Tellurium. Their atomic weights are as though two weights of Sulphur had been taken to make Selenium, and two of Selenium to make Tellurium.

What is Sulphur?

It is a yellow earth-like solid, coarse-grained and tasteless. It melts



THE BARON JUSTUS VON LIEBIG, CHIEF FOUNDER OF ORGANIC CHEMISTRY.

into a thin liquid. At a heat of say 425 degrees Fahrenheit it gets so thick that it will not run, and is dark. At about 900 degrees it boils, producing an orange-colored vapor. It makes various crystals, and, like Carbon, Oxygen, Nitrogen and the other Allotropic Elements, may be the hiding-place of new Elements yet to be isolated.

What is Brimstone?

Brimstone is Sulphur. Brimstone is the old name, meaning *burning stone*, because this stone, or stick, set on fire like hard coal, would make a fume, and this fume would bleach cloth or straw, or would kill insects or bacteria in rooms. Animal hair

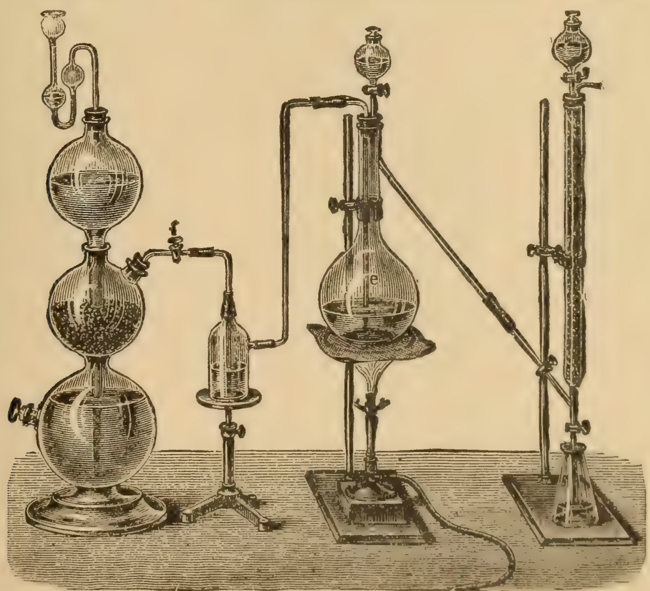


Fig. 107. APPARATUS FOR FINDING AND MEASURING SULPHUR.

has 4 per cent. of this Element. The Albuminoids and all vegetable and animal cells have molecules of Sulphur. Sulphur is the predominating Element in Asafœtida, Mustard, Onions and Garlic. It is present in Eggs. Sicily, California and Louisiana are the chief commercial sources of Brimstone, or Elementary Sulphur. It is mined in tunnels and shafts sometimes 325 feet deep

What does Thio mean?

Sulphur, from the Greek word *theion*, Sulphur. There are nine kinds of Sulphur Acid, all made of Hydrogen, Sulphur, Oxygen. In all of them two atoms of Hydrogen are used, and from one to five atoms of Sulphur join in the molecule. This presses the chemists for names, and they resort to *thio*. The nine Sulphur acids take the following names, the molecules with fewest atoms coming first in the list: Hyposulphurous Acid, Sulphurous Acid, Sulphuric Acid, Thiosulphuric Acid, Anhydrosulphuric Acid, Dithionic (two Sulphur atoms) Acid, Trithionic (three) Acid, Tetrathionic (four) Acid, and Pentathionic (five) Acid. In each of the last four Acids there are six atoms of Oxygen.

What are the uses of Sulphur?

The Element itself is largely used to make Sulphuric Acid, and for fifty years the scientists have claimed that the quantity of Sulphuric Acid *per capita* used by any nation was the best gauge of its advancement in civilization and comfort. Besides Sulphuric Acid, Sulphur is used in gunpowder; in various cements, especially for electrical isolation; for the vulcanization (that is, practically, the utilization) of India-rubber; for the protection of plants threatened by insects; in the taking of casts, etc.

What is Sulphuric Acid used for?

You have its effects in all cloths and papers that have been bleached, in all brushes; in nearly all leathers. You will note its use in Sugar-making. There is no art that has not found itself indebted to this compound. It is used in making fertilizers, and in smelting. It has been the efficient agent of the chemist in every laboratory.

How does Sulphuric Acid look?

It is a dense, colorless, oily liquid known popularly as the Oil of Vitriol. It has no smell, and is nearly twice as heavy as water. Its acid taste is renowned in the adjective *vitriolic*, which, in English, is usually taken to mean all that is biting and resentful.

Give the uses of other Sulphur compounds.

Sulphuretted Hydrogen is used for tests in the laboratory. The Chloride of Sulphur is used in making sheet rubber. Sulphurous Acid is a great bleaching and clarifying agent, it being merely a weaker compound than Sulphuric Acid. Hyposulphite of Soda is used in photography and paper-making. The Sulphates of Ammonia (Nitrogen), of Potassium, of Sodium, of Lime (Calcium), of Barium (called Barytes), of Magnesium (called Epsom Salts), and of Iron (called Copperas), as well as Gypsum (Calcium), play leading parts in the drama of our commercial industries. The Sulphate of Aluminium is the active ingredient in Alum, and makes the size for paper. The beautiful blue crystals which you associate with Electricity and all wet batteries, are Sulphate of Copper. This is blue vitriol, and the Electrotyper and all other Electrolyzers use it. In medicine, the Sulphates are often administered with the commonest medicines as an aid to their dissolution in the human system, and this is conspicuously true of Quinine, which is a Sulphate.

What is Quinine?

In the seventeenth century the wife of Count Cinchon, viceroy of Peru, was cured of intermittent fever by the bark of trees growing on the Andes, and took the medicine to Spain. There it was called Peruvian Bark and Jesuits' Bark. From this red bark a white, fleecy powder is made—the Sulphate. The method of obtaining this powder has always been kept as a chemical secret, but improving chemistry has greatly cheapened the expense. The formula of our Quinine shows only one atom of Sulphur in one hundred and nine atoms, and is given as follows:

$$(C_{20}H_{24}N_2O_2)_2 . H_2SO_4 + 2H_2O.$$

That is to say that two of the combinations named in the parenthesis cling especially together; this double molecule clings *very* closely to the molecule with the Sulphur atom in it—H_2SO_4—and there are also two molecules of water that may come or go, according to the heat, and sometimes the water increases. Quinine, under a doctor's order, is one of the best medicines that man possesses.

Describe Selenium and Tellurium.

Selenium is Allotropic or changeable, like Sulphur and Carbon. (See Radiophone.) As a metal it would break like gray cast iron. It was isolated in 1817 by Berzelius. Tellurium is a silver-white resplendent metal. It was isolated by Muller von Reichenstein in 1782. Both these Elements occur only in rare ores. Selenium was named after the moon and Tellurium after the earth. With Sulphur, as gases, they combine with Hydrogen as H_2S, or H_2Se, or H_2Te, which makes a substance akin to water (H_2O). All the rare metals are preserved in naphtha or petroleum.

What is Phosphorus?

An Element of a light amber color, semi-transparent when first isolated. It becomes opaque, and looks like whitish wax.

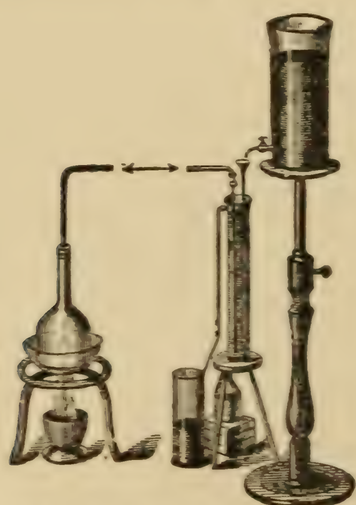


Fig. [illegible]. MITSCHERLICH'S APPARATUS FOR THE DETERMINATION OF PHOSPHORUS.

It is never found pure, and is isolated only after an extended process. It emits a white smoke when exposed to the air, and takes fire at a temperature a little below blood heat. It shines

in the dark. It is a virulent poison. It is Allotropic, like Carbon, Sulphur, etc., and its commonest Allotropic form is known to us in Red Precipitate, which goes back to the whitish wax under the action of heat. It was isolated by Brand, a German alchemist, in 1678, who thought he had now discovered a substance that would "ennoble" Silver into Gold. But he had done something far more wonderful, by making Matches possible. (See Matches.)

How does Nature use Phosphorus?

Always as a salt of Phosphoric Acid, which is H_3PO_4. These Phosphates are present in most soils, rocks, and river and spring waters. Phosphates are necessary to the life of plants and animals. In plants they are found in the sea. In animals Calcium Phosphate is the main part of the bones, and Phosphates are an important part of the blood and tissue.

How does man use Phosphorus?

Chiefly in match-making. We also import millions of dollars' worth of phosphates for fertilizers. Phosphorus plays an important part in the manufacture of Iodide of Methyl, for Aniline dyes. Phosphorus paste, or red ointment, is a renowned destroyer of all vermin. It is mixed with flour. Medical men are giving attention to the administration of Hyphosphites—that is, Hypophosphorous Acid (HPH_2O_2), with a base like Sulphur, Quinine, Strychnine, Opium, etc. Acid Phosphates have become popular as tonics, on the theory that they furnish food that indoor life denies. On all these matters, the advice of a physician is at all times necessary.

What is Boron?

A dark brown powder, or also a powder made of brown crystals which are nearly as hard as diamonds and as powerful in reflecting light. It is thus Allotropic.

What is Borax?

Borax is the biborate of Sodium—$Na_2B_4O_7$. It is used in our households for cleansing purposes. It was once called Tincal, and came to India from Thibet, and thence to the rest of the world. It forms on the bottom of a lake in Dead Man's Land,

California, and is hauled out of that forsaken country in the largest wagons ever used, drawn by ten teams of mules. This deposit is the best borax that has been found, and can be used by assayers in its crude state. Borax is of special value in the melting and refining of ores, in glass-making and pottery. It is used as a preservative of meats, for detergent soaps and washing compounds, and as a gargle in medicines. Boracic Acid enters into the fancy grades of matches, and a fine lacquer for carriages and railway cars is made by the aid of Borate of Manganese.

What is Silicon?

The leading Element of the earth's crust, in rocks and sand. It was isolated by Berzelius in 1823. It is Allotropic, or changeable. It is a dull brown powder, called *amorphous* (without form) Silicon. It may be converted by heat into a substance like Graphite. It may also be obtained in large, beautiful iron gray needles called *adamantine* Silicon. Its Oxide is Silica, of which there are four kinds, and three of them, quartz, sand and opal, are well known. Silica is made into glass, paint and soap. Where a metal is added to Silica (sand) the compound becomes a Silicate. Silicon has many of the peculiarities of Carbon. Silica (sand) was considered absolutely non-volatile, until 1896. In that year M. Moissan turned it into a violet colored gas. It is proof against the action of water and ordinary mineral acids. This makes it especially valuable as a material for plaster, cement, pottery, etc. The following atoms $4Si\ H\ (OC_3H_5)_3$ form a molecule in a compound which has a particularly long name—Triethylsiliconorthoformate. Here we may espy "Three-ether sour radicle-silicon-straight-red-ant-like." The sign shows two groups of molecules—the first being four molecules of Silicon-Hydrogen, the second being three molecules, each having one Oxygen, three Carbons, five Hydrogen atoms. All these are organized as one greater molecule. The sign for the sand at the lake or sea shore is SiO_2. There is, of course, a process in nature where Silicon becomes a gelatin, and may pass into the structures of vegetable and animal things, but the process has not yet been discovered.

What is the Alkali group of Metals?

Lithium, Sodium, Potassium, Rubidium, Cæsium. These are white metals, which turn to gas only at high temperatures. Lithium gives a red color to flame; Sodium salts an intense yellow; and Potassium, Rubidium and Cæsium a violet. Cæsium has not been completely isolated, but is a liquid metal.

What is the history of Lithium?

It was discovered by Arfvedson in 1817. The metal was successfully isolated in 1855 by Bunsen. It weighs only six-tenths as much as water and floats in petroleum, where it must be kept, to prevent mixture with Oxygen. The Lithia salts are held in high esteem in mineral waters, and some of these springs have been famous in America for over a century.

What are the uses of Sodium?

We have spoken of this Element in the Chapters on Bread, Salt, Soap and elsewhere. It is an abundant substance, but nowhere free. It is prepared commercially in cakes of metal, wrapped in paraffine paper to prevent oxidation, and packed closely in tin boxes. The process of converting salt into Soda is regarded by some chemists as the most valuable and fertile discovery of all times. It was the conception of Le Blanc, who killed himself in a workhouse at Paris. He added chalk to a sulphate and charcoal mixture, and fluxed the whole in crucibles, obtaining the Soda for which the Academy had long before offered a prize.

What is Salt made into at the Soda factories?

Into Chlorate of Soda for Aniline black colors; into Carbonate of Soda (Soda) into salt-cake for glass and caustic Soda and black ash for soap. Washing Soda (Sal Soda) is made of crystals of Sodium, Carbon, Oxygen and Hydrogen. In many industrial ways the two great alkalis, Sodium and Potassium, are in close connection. We must not forget the important part that Sodium plays at our Soda fountains, which, in latter days, have risen as the most powerful rivals the dram shops have ever had. By means of the Soda fountain, the list of beverages, medicines and chemicals administered is yearly growing more voluminous.

What is Potassium?

The more abundant and important of the two great alkalis, the other one being Sodium. All vegetables draw up into their fibres far more Potassium than Sodium. Herbs contain a larger percentage than trees. Potassium is a bluish white, soft metal, lighter than water. It is obtained in a compound form, generally with Carbon, Sulphur, Chlorine and Oxygen, by running water through wood ashes and boiling down the lye into potash. This potash, or concentrated lye, may be purified into pearl ash. Wood-burning industries still flourish in Hungary for the sole purpose of making potash. We export many hundreds of thousands of pounds of pot and pearl ash. The commercial name is Potash, and Chlorate, Muriate (Chloride), Nitrate (Saltpetre) and many other forms are imported in great quantities, but not as freely as the Sodas. The greatest Potash industry is at the salt wells of Stassfurt in Germany.

What are the chief uses of Potassium?

For soap, for glass, for baking powder, for medicine, as a preservative of meats and other perishable products, for bleaching, for photo-engraving, for gunpowder and for fireworks, In soap and glass-making and baking, the connection with Sodium is very close.

What will the four metals in this group do that is peculiar?

A pellet of Potassium, etc., thrown upon water at once bursts into a violet flame, and the burning metal floats upon the water without much contact. When the last remnant, through cooling, is wet by the water, there is an explosion. It is the Hydrogen that burns, and the Potassium fumes that give the color. Thus water is actually decomposed.

What is Saltpetre?

It is a combination of one atom of Potassium, one of Nitrogen, and three of Oxygen. These atoms come together on the surface of the earth in India and on the Chilian coast. Saltpetre is used for the making of Nitric Acid by the meat-canners and packers, by the gunpowder-makers, and the manufacturers of fireworks.

What is Gunpowder?

Gunpowder is a dry mixture of about seventy-five parts Saltpetre, thirteen parts charcoal, and twelve parts Sulphur. Saltpetre holds three thousand times as much Oxygen as air of the same bulk. Sudden heat liberates this Oxygen, it combines with the Carbon in the Charcoal to make carbonic acid and other gases, while the Potassium in the Saltpetre, having served its purpose, drops back after the explosion, into the residue or ashes. This mixture practically put an end to walled cities, and gave Europe the control of Asia and America.

What Potassiums are used in Photography?

The Iodide and the Bromide. The Iodide is the great medicine which eliminates Mercury from the human system, and attacks skin diseases. Potassium is in Prussic Acid, Oxalic acid, the Cream of Tartar of our baking powders; in the Sulphates; in many paints and colors.

What are the uses of Chlorate of Potassium?

It is the great agent of the artillerists, the match-makers, and the pyrotechnists or makers of fireworks. The salt is permanent when exposed to the air. Mixed with combustibles, it serves as a store of highly condensed Oxygen atoms, and on their liberation and expansion heat must rapidly develop.

What is to be further said of Cæsium and Rubidium?

These metals, completing the group, are treated with Potassium in the books. Cæsium is remarkable as being the most positive in its Electrical action of all the Elements. Both Cæsium and Rubidium were discovered by Kirchoff and Bunsen, in 1860–1, by the Spectroscope. Rubidium and Cæsium are separated with the greatest difficulty, and their molecules are present in sea water.

Pass now to the Metals of the Alkaline Earths.

In this group of the eighty-five or more Elements are Calcium, Strontium and Barium. Of these you hear much of Calcium and Barium. In *Calcimine*, *Calcine*, *Calc*, *Calcareous*, and in Barytes, a material for paint, fireworks and adulterants, you may readily place the two Elements. When you see "red

fire," it is the combustion of crystals formed of one atom of Strontium, two of Sodium and ten of Oxygen.

Is Calcium an important Element?

Yes. The people deal with it familiarly as lime in its countless uses, but chiefly as a part of the leading cement of the world, whereby all brick and stone walls are made. It is a leading component of our glassware. Lime is the Oxide of Calcium. Calcium is a light yellow metal, softer than gold, and very ductile. It is one of the chief Elements of the solid earth. These three Elements, like the group that preceded, decompose water, and drive or let off the Hydrogen, but less readily. They burn with the greatest brilliancy when ignited in air. The Calcium light of our boyhood days was the precursor of the Electric light. The Calcium light now bids fair to come back to us, as one of the great factories at Niagara Falls is making Calcium Carbide for Acetylene gas. Strontium is a deeper yellow metal, and Barium is supposed to closely resemble it.

What is the Magnesium Group?

Glucinum, Magnesium, Zinc, Cadmium and Mercury. Glucinum was called Beryllium, because it was discovered in the beryl and emerald. Glucinum is from a Greek word for *sweet.*

How is the Emerald crystal made?

It is theorized as a molecule of three Glucinum and three Oxygen atoms, clinging to a molecule of two Aluminium and three Oxygen atoms, and these cling to a larger molecule of six Silicon and twelve Oxygen atoms, the latter themselves organized. Glucinum is closely related to Zinc and Mercury. It is a white malleable metal. It was isolated in 1798 by Vaquelin.

What is Zinc?

A rather hard bluish white metal now well known to the people, but once only known in its Carbonate, called Calamine stone. It was used in the making of brass, and largely for brass jewelry. It was called Spelter, but Pewter was a compound of other metals. The Chinese sent Zinc to India, and thence it reached England. We know it best in the household on account of the Zinc-board under our stoves, our so-called Galvanized

wires, which are merely dipped in Zinc, and our hot-water boilers. But it forms one-third of the material for all our pins (with Copper). Zinc is an important part of shining brass which enters more and more into the handsome trimmings of our doors and windows, our faucets, and the ornaments of machinery, although Nickel has become a substitute for stove decoration, and in other ways. Zinc has served as the basis of most of the newspaper pictures. It is a good metal for casts.

What is White Zinc?

It is the Oxide. This has come into great use as a substitute or adulterant of White Lead, the main pigment of civilization. It does not cover so well as White Lead paint, but it is not poisonous, and does not discolor in the Sulphurous atmosphere of a city. The Zinc we see is not so pure as the Element Zinc, yet there is no great difference.

What is Cadmium?

It is an Element usually present with commercial Zinc, but improves the metallic compound. Both Zinc and Cadmium with Magnesium are bluish white metals which will shine in dry air, but in moist air gather the greasy film familiar on the surface of Zinc, which is a thin Oxide.

What is Magnesium?

It is a metal more like Silver than its fellow-metals. In its Oxide, which we call Magnesia, it is disseminated throughout nature, in earth, rocks and water, forming one of the materials without which life would cease. Pure Magnesium, before the days of the Electric light, was sold in ribbons or wires, for the purpose of furnishing a brilliant light. The wire might be lit in a candle-flame, and would then burn by itself.

How do we best know Magnesium?

At the drug-store, for our physicians use it as a leading therapeutic agent. Epsom Salts, Citrate of Magnesia, and other compounds are still used as anti-acids or as purgatives of more or less force, as required. Magnesia has been used largely in dealing with the troubles of infancy.

What are the important Silicates of Magnesium?

Asbestos and Meerschaum. There are mountain masses of various Silicates. Asbestos, as we see it in our gas-grates, is the name of a group of the Hornblende family of mineral rocks, and usually contains Magnesia, Alumina, Silica and Oxide of Iron. The molecule of Meerschaum is extremely complex, and various theories exist in regard to it.

I desire to know more about Asbestos.

The greatest mines are in Canada, in the eastern part of Quebec. One twenty-fifth of the rock quarried is Asbestos. The mineral wool is taken to the United States in train loads. The stuff is fed into a stone process grinding mill. After it is ground or crushed, it is separated into long and short fibres. The short fibres go to the pulp mill, where they are ground fine for packing around steam pistons, hot pipes, valves, etc. The long fibres are spun into yarn, like wool. The cloth from this yarn has a soapy or greasy feel. Theatre curtains may be made of this cloth. Asbestos is put in vulcanized rubber and used as an insulator. No acid will act on it, therefore the chemist uses it all the time.

What is Mercury?

The last and most important metal of the group we are passing in review. We often call it Quicksilver. The older nations following the Greeks, called it Silver Water, hence its chemical name Hydrargyrum. Our household use of Mercury was once on our looking-glasses, and is now in our thermometers, and in our Calomel and Blue Pill, our Corrosive Sublimate, and our red paint called Cinnabar. Mercury has been one of the three great sources of red colors for ages, and the Cinnabar (Vermilion) mines of Spain are the oldest works of the mining order in existence. Calomel is a compound of Mercury and Chlorine. Cinnabar is a union of Sulphur and Mercury. Tin was mixed with Mercury for the backs of mirrors before the Silver process was used.

Why do we call it Quicksilver?

Because the Latins named it Live Silver—*argentum vivum.* It is a fluid, as you know, of great weight, and its globules, in

seeking the lowest place, when they were spilled, acted as if they were *alive*. *Quick* was an old English synonym of the word *alive*.

What great uses for Mercury outside of the household can you name?

Its chief use is probably in extracting Gold at the mines. The vacuum-pumps where glass-bulbs are sealed are worked with Mercury. Fulminate of Mercury is the explosive by which dynamite and other blasts are fired. Good clocks swing Mercury pendulums. There are unnumbered uses in the laboratory.

Why are Copper, Silver and Gold grouped?

Because they bear certain relations to the Alkali metals, best seen in Silver. These three Elements are the ones that man first held in high esteem, nor does he yet cease to value them highly.

What is Copper?

A beautiful red metal, of great Electrical conductivity, of great ductility and tenacity. It is not dissolved by water, and does not oxidize in the air. It was the first metal known to man, and with tin formed the bronze which enabled our race to rise above the Stone Age. The Electric Age has given it an increased value, as the trolley wire and the armature of the Dynamo testify. (See Electricity.)

What are its other uses?

Sheets of copper frequently underlie the nickel and silver polish of our household utensils. The tin tea-kettle has a copper fire-bottom, and many stove-vessels have flat copper bottoms. Two-thirds of the inside metal in all our pins is copper, the other third being zinc. The cent in our pockets is copper, and the money of China is largely copper. The gasolier is usually of copper. The blue light at the drug-store is cast by a copper solution in a bottle. The hot-water tank or boiler in the city kitchen is often of copper. But the great and striking use is in the manufactories where liquids are boiled, whether it be sugar-cane juice, beets, malt, corn, starch,—stills, condensers, neutralizers, boilers, vacuum-pans, milk-vats—all are shining copper, because of the fair degree of neutrality of the copper molecules. Ships are bottomed with copper-plates.

What is the Copper Half-tone?

A photograph transferred to a plate of Copper, and also further engraved by hand, which prints with photographic effect. The Copper-plates thus taken of the World's Fairs and their exhibits, might be measured by the square mile. The making of these pictures has lowered the price of some of the magazines, and the people are now offered ideas of the drawing and lights of the celebrated paintings of the world, and of city and landscape scenes that were formerly possessed only by travelers.

What are the great Copper chemicals?

The Acetate of Copper, or Verdigris, is made like white lead. It is used as a pigment, both in water and oil painting and also for dyes. Carbonate of Copper furnishes the paints called Verditer, Bremen Blue and Bremen Green. Sulphate of Copper is Blue Vitriol, which you may see in an Electric battery. It is also used in calico-printing and silver mining. Copper and Arsenic give the mineral greens, and are very poisonous. Black, red and yellow may also be produced easily. It is the Blue Vitriol that the chemists usually choose as a basis from which to secure other Copper Compounds.

What is Silver?

Silver is a beautiful white metal, harder than Gold, but softer than Copper. It forms the coined money of every-day life in all the nations west of Asia, and is rapidly coming into the same usefulness there. It was known to man and used as money at an early date in the Bronze Age, although for a thousand years it was cut and weighed in balances by the shekel and maneh. In our coins it is alloyed with one-tenth of Copper. It has greatly cheapened in price during the past three decades.

Why do we say Silver-plate?

Because the early method of uniting Silver on Copper was by coating an ingot of Copper with Borax and laying an ingot of Silver on top. The two ingots were then heated, and the Borax, as a flux, fused the two metals, and they were then rolled out into sheets of Silver on one side and Copper on the other. The

process of Electrolysis, or Electro-plating displaced the old plate-making, and "Silver plate" is not now-a-days necessarily such in fact. Three-fourths of the Silver is used in the household, for spoons, ornaments, watches, etc.

What are the Silver chemicals?

The Silver Haloids (Iodine, Bromine, Chlorine, etc.) are remarkable on account of their sensitiveness to light. Hence Silver is the chief Element in the Photographer's gallery. Indelible ink was first made with Silver. Lunar caustic, hair dyes, and fulminates are made from Silver.

How are Looking-Glasses made?

The process was once one in which Quicksilver (Mercury) was the leading material for coating the glass, but Silver has entirely replaced Mercury, and now-a-days there is no menace to health in the factories where mirrors are made.

What is Gold?

Gold is a yellow metal of great weight, but not hard enough in its pure state for the making of coin. It is composed of fine molecules which cling together with the greatest tenacity known, so that a gold wire may be drawn out to almost incredible length. Gold is impervious to the atmosphere, and can only be turned into vapor with great and continued heat, many scientists having lived and died in the belief that continued fusion did not lessen the volume of gold in the crucible. It may be dissipated, when in gold leaf, by a heavy charge of Electricity. It crystallizes in various forms and colors, and possesses a perplexing Allotropic character, when its otherwise apparent purity and homogeneity are considered. How it takes its various colors without mixture with the coloring matter has not been theorized. Hence chemists are still in hopes of gold-making discoveries.

What is the history of Gold?

Gold was not probably known until after the discovery and isolation of Copper, Tin and Iron. It was not used as money, or perhaps even known in the early cities of Shinar, or in the hills at Nineveh. The Egyptians "cupelled" it, as is done to-day. It has been reckoned as the most precious of possessions

for the better part of 5,000 years, and during the last thirty years has been adopted as the standard of value by over half the world's population, following the lead of Great Britain, early in the nineteenth century. The gold standard was fully adopted by Congress and President Harrison in July, 1890, when Silver was bought by the Government at the bullion price in Gold in London. The discovery of new supplies of Gold has not met the new demands, although one of the greatest speculations of modern times has gone forward in South African mines, where the Cyanide process reduced the cost of extraction, and large quantities of the precious metals have been found on the shores and in the river-beds of Alaska.

How do the mining experts guess so nearly to the value of gold and silver-bearing rock?

Here is one of their formulas: Let W represent the specific gravity of the specimen in air; A, the same in water; D, the difference in ounces or fractions; B, the known specific gravity of the metal (varying according to circumstances from 15.6 to 19.34); C, the known specific gravity of the gangue (ore, quartz, rock), namely, if SiO_3, it equals 2.65. Now, with these capital letters thus defined, WB minus BCD divided by B minus C, equals the ounces in gold in a ton of the gangue.

What are the Gold chemicals?

They are practically all in the Halogens (Iodine, Chlorine, Bromine, etc.), or in their compounds. Gold makes an explosive. The statement of Dr. Keeley, of the little town of Dwight, Ill., made about 1888, that by a double Chloride of Gold, injected in the blood of a patient, he could overcome the periodic desire of the subject for alcoholic drink, probably marked one of the most interesting ethnological episodes in history. A molecule of Potassium and Chlorine, one atom each, may be united to a molecule of Gold and Chlorine, the latter molecule containing three atoms of Chlorine. If the Potassium be taken away, we have left the medicine, or the analogue of the secret medicine, which Dr. Keeley administered. Not only did the town of Dwight serve as a sanitarium for hundreds of thousands of patients—coming from the most gifted classes of

the people, but branches of the Gold Cure were established in every State, laws were passed encouraging the Cure, and imitatory hospitals were set up all over the world.

What metals compose the Lead Group?

Lead and Thallium. Lead is one of the most important of the Elements, although like Mercury and Copper, it is a poison. Its greatest use is for water pipes, because water, the great dissolvent, makes no inroads on the walls of Lead. Its next great use is for paint, as White Lead—the Carbonate. It is used in glass-making. White Lead is the be-all and end-all of the paint we buy and use. Again, war has made "the leaden messenger of death" a theme of poets and historians. But though Lead have brought death with its bullets, it has also with its printing-types brought light, and the invention of type-casting machines to take the places of type-setters has only enlarged the uses to which Lead may be put.

How is Lead-Pipe made?

It may be rolled by rollers around a core or mandrel; or it may be squeezed out of an annular hole in a hydrostatic press, as macaroni tubes are made. The latter method is most rapid, and makes a continuous coil. All houses in cities are served with Lead pipe out to the iron water-pipe in the street.

What are the principal Lead compounds?

In type, Lead, Copper and Antimony. In shot and bullets, Lead and Arsenic. In paint, Lead and Carbon, or Oxygen as in Minium (Red Lead). White Lead is made by Carbonizing sheets of Lead in Vinegar pots under heaps of tan-bark. Lead, as a solder is extremely ancient, and is yet used in stone and Iron work, as the most reliable Element through which protection may be gained against the tooth of time. In cemeteries, we may see that the most enduring tombs have been constructed of polished granite with obtruding seams of Lead. Thus frost can obtain no leverage among the molecules. The tinner's solder is a compound of Tin and Lead. Stereotype plates are made with Lead, Antimony and Bismuth.

What is Litharge?

Litharge, as well as the commercial "Massicot," is the scum of melting good Lead. Out of Litharge the Lead medicines are usually made. Sugar of Lead is a valuable application, with Opium, on skin eruptions of a fiery and spreading order, like erysipelas. Lead is mined all over the world.

What is Thallium?

It was isolated by Professor Crookes, of the Crookes tubes, in 1862. It looks like Zinc, but is even softer than Lead. It is also heavier than Lead. It exists in small quantity in a rare and wonderful ore called Crooksite, found in Sweden. This ore is formed of Selenium, Copper, Silver and Thallium. In the Spectrum, Thallium shows but a single line.

What is Aluminium?

A very light, very hard, steel-like, Silvery metal, found to be the chief constituent with Oxygen, of our common clay. Alumina would be pure clay, without Silica, and pure clay would be the mineral Sapphire. Aluminium has created as much interest as the X Ray. It was once dearer than Gold, and only after the invention of the commercial Dynamo and by Electrical means, could the metal be forced from its seat in the blue clay which we behold on every hand. Works are established at Niagara Falls, and Aluminium increases in use. The household sees it chiefly in medals, ornaments and light utensils. The steel-makers use it in steel. Cash-registers, mine-chains, war vessels and flying machines deal with it.

How is Aluminium extracted from clay?

A crucible is made of Carbon blocks, with a bottom tap-hole. This crucible is filled with pieces of clay. An enormous Carbon candle or Electrode is lowered into the mass and a current of 14,000 amperes, 30 volts, 1,500,000 watts (see Electricity) is sent from the candle through the crucible. That is, a monster arc light is set up. Chunks of Copper are put in the clay as aiding negative Electrodes. Under this heat the Aluminium separates, and may be tapped out four hundred pounds a day. Poisonous gases pour from the chimneys, as from the Soda factories.

What is Indium?

It is a white, heavy metal, always associated with Zinc, closely allied with Aluminium in nature, discovered as late as 1863. Reich and Richter were searching for Thallium with the spectroscope when they saw a new Indigo blue line. So they named the Element Indium when they found it, as Indigo gets its name through the Latin languages from India, whence it came.

What is the Iron Group?

Chromium, Manganese, Iron, Cobalt and Nickel. As you will observe by their names, none of them is new save Chromium. They are closely related.

What is Iron?

Our most useful metal. Man and his history are best studied in Ages—the rough Stone Age, the hewn Stone Age, the Bronze Age and the Iron Age. The latter, like the Stone Age, may be divided into two chapters, the invention of the steam engine by Watt marking the last and greatest change in the condition of man.

Why is Iron so useful?

Because it can be fused and welded into innumerable shapes. With tempering or with mere return to ordinary temperature, it becomes an adamant, the strongest of our Elementary substances, and also the tool by which nearly all of them may be wrought into shape. Our machines are nearly all of Iron, and eighty per cent. of the work of the world is done by Iron arms. Our horses are made of Iron. Our ships are Iron. Our bridges are Iron. At last, our buildings are Iron, and the era when man's constructive toil shall be at end bids soon to dawn.

What is Steel?

Iron and Carbon with other Elements like Aluminium in some small proportion. In the Bessemer process an astonishing Converter is used—an open mortar or vast cannon out of which a shaft of fiery air is blown from the fused metal inside. In this way a portion of the Carbon is burned out.

What is the chemical use of Iron?

It is a noble medicine, imparting the *red* essential to our blood. Some forty or more Iron compounds are used by the physicians. In most of the conditions where the patient is too white, relief should be found in this great tonic, although only through the advice of a physician, as Iron might serve to increase heat and inflammation, thus shortening life. Fear of harming the teeth and alarm from the discoloration of ingested matter are exaggerated by the people.

What is Chromium?

It is an Allotropic metal, having three Elementary conditions —a gray powder, shining crystals, and a very hard steel gray metal. It was named from the Greek *chroma*, color. The English word *chrome* asserts the presence of Chromium in all the ores called chromes, found in so many parts of the United States.

What are the Chromium paints?

Lead Chromate is a great red. The sixth Oxide of Chromium is a valuable green, used on our bank-notes, and in glass-staining. Emerald greens are Hydrates of Chromium. Guignet's Green is a Borate of Chromium. Plessy's Green is a Phosphate of Chromium. It is one of the colors used in pink chinaware.

To what other uses is Chromium put?

The calico-printers use it, and it bleaches tallow and palm oil. Chromeisen, that is, Chrome-iron, will cut glass. The Bichromate is used by photographers, chemists and Electricians. Chromium glue repairs broken glass or porcelain vessels of value, as water will not dissolve it.

What is Manganese?

A soft, brittle, grayish white metal, very useful in affording a method of liberating Chlorine from its common compounds. In its union with Potassium, Manganese offers the most chameleon-like phenomena, and was called "the chameleon mineral" by the ancients. Here we may have an intensely green mass. An acid will turn it intensely purple. An alkali will reconvert it to green. Put in Chlorine, and purple fluid may be

secured, which will make black crystals, with green or blueish hue. Grind them, and the powder is red. A grain of this powder will color all the water of a great vessel. Add an acid to the purple mixture and it becomes pink.

What does Per mean?

*Per*manganate or *per*oxide means the greatest number of atoms of Manganese or Oxygen used in any Manganese or Oxygen compound.

What uses is Manganese put to?

Is is a noted disinfectant, because it oxidizes so many substances, and it is a tool in the laboratory for the oxidization of any Element, and the measure of its complete oxidization. It is a tonic medicine.

Where is it found?

It usually is in company with Iron, Calcium and Magnesium, and is as widely diffused over the earth as its companions. The deep sea expedition of the ship "Challenger" brought back Manganese nodules scraped from the bottom of the ocean. These cover large areas of the ocean's bed.

What is Cobalt?

It is a heavy, steel gray metal with a reddish tint, taking a high lustre in polishing. The German name *Kobold*, applied to the original mineral, by the miners, signified *evil spirit* or *bad luck*, as the Cobalt was often found where Silver ore was desired.

For what is Cobalt famous?

In 1540, Scheurer found that the Oxide of Cobalt would color glass, and until then it was supposed to be useless. Where you see a sign-board with a shining-blue background, which sparkles like so many snow crystals, you see the painter's *smalts*. To make this, Silica and Carbonate of Potassium with Cobalt Oxide are fused into glass, the glass is ground into powder between granite mill-stones, and mixed with paint-vehicles. You note the beauty of such sign-board backgrounds, long after their surroundings have faded, and it is possible that the vitreous Cobalt blue is the only color of its hue that does not rapidly

change or fade under the influence of light and air. Cobalt is the blue of nearly all porcelain. It was once the main color used for blue wall papers.

What is Nickel?

This, like Aluminium, is another of the great metals of our modern life. It is a shining white Element, very heavy, very hard, and rather more impervious to the action of air than Silver. It was isolated by Cronsted in 1751, who named it from goblin-copper—Kupfer-nickel—that is, Old Nick's Copper, or the devil's copper, false in performance of promise. In America, it made the acquaintance of the people in the Eagle Cent of 1857. And yet it was not until 1879 that Fleitman, by adding Magnesium to his molten Nickel, was able to roll it out with Iron in a fused sheet, as Silver and Copper were once rolled. Nickel vessels are thus made in England. But already, in the United States, a decade earlier, our Electrolyzers (see Electrolysis) had put the Galvanic Battery at work on the lines of Bottcher in 1848, and given to the stoves of our households and stores, the gleaming ornaments that now generally adorn them. Nickel-plate was so popular, that a great railroad undertaking was so named as an advertisement, and the plumbers and house hardware-furnishers at once made the most of the easy Electric union of Nickel with iron and copper. Among the household conveniences that have clearly demonstrated to us the value of Nickel-plate is the "student lamp." At the great iron-works, armor-plates for war-vessels are often plated with Nickel. Probably our greatest use of Nickel is on stoves.

What is the Platinum Group?

It is composed of Ruthenium, Rhodium, Palladium, Osmium, Iridium and Platinum. They are all white metals, and are found together, in their native molecules. Osmium is one of the heavy Elements, and possibly the most difficult to fuse. The international standard of length, for the measurement of the earth, adopted in 1883, is wrought of an alloy of Platinum, Iridium, Rhodium, Ruthenium and Iron. This is supposed to give a metal bar that will change the least possible degree

under the ordinarily varying temperatures. All these metals make good points for gold pens.

How are these Metals obtained?

From a rare ore called Polyxene. There is usually a trace of Platinum in native Gold. It was the early workers in Platinum, like Wollaston, who in time determined the presence in Platinum ore of the other heavy metals. Platinum was one of the discoveries of the Spanish sailors who came to America.

What are the uses of Platinum?

Russia coined money of Platinum, but was forced to recall the coinage, because of its fluctuating value. Liebig said that without Platinum crucibles, the composition of most minerals

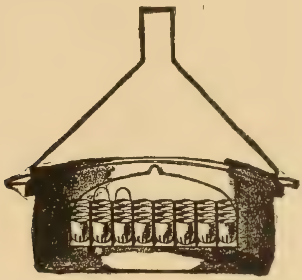


Fig. 108. PLATINUM APPARATUS FOR ASSAYING PRECIOUS METALS.

could not have been ascertained. Sulphuric Acid, the agent of civilization, is made most economically in a Platinum still, which costs a fortune. Platinum, variously treated, has out-rivaled the oxide of Iron as a catalytic (See Catalysis) in the production of Sulphuric Acid at the greatest establishments, Germany especially. The union of Platinum and Cyanogen (NH) is interesting to Electricians and other scientists on account of its fluorescence. (See X Rays.) Platinum is still very costly.

What is the Tin Group?

The Elements called Titanium, Zirconium and Tin form this family. Of the uses of Zirconium we shall speak in treating the Cerium group, anon.

What is the history of Tin?

Here we again approach one of the metals that is more ancient than the written or even the traditionary history of mankind. The metal that today serves the housewife so perfectly, protecting her iron utensils from the action of air and acids, was also the earliest means of enabling man to throw away his stone axe and knife. When Copper was found at Cypress, Tin was brought from Cornwall to mix with it into bronze. We must admire the courage of the Phœnician merchants who, before the days of Ulysses, sailed out of the Pillars of Hercules, where now Gibraltar stands, and crossed the stormy Bay of Biscay into the cold northern land to obtain the shining metal, then called White Lead. Doubtless it was the bronze axe that made Egypt mistress of the world.

Describe the Element Tin.

It is a white metal, bright and silvery, although there is a slight oxidation in the air which, however, may be easily removed. It is slightly elastic and sonorous. It is very light and fuses at a comparatively low temperature. Few metals are so well known and so much used as Tin, and yet few are so seldom seen in any but the filmy form of tin-plate, so-called, on our pans and kitchen vessels, or as tin-foil wrapping our chocolates, tobaccos, etc.

How is Tin obtained?

It is in an ore called Tin-stone or Cassiterite, the native Oxide of Tin. It is believed that in ancient times the inhabitants of the British Isles washed the stones from the bottoms of their creeks, and traded them for the glass and dyed cloths of the Phœnicians. Pick-axes made of the horns of animals are found in these tin-works. Diodorus of Sicily states that the barbarians carried their Tin-stones in little carts at low water to barter with the merchants.

Were Tin mines dug later?

Yes, and to great distances under the sea. The Duke of Cornwall for centuries derived a revenue from the product of all the Tin mines. The Prince of Wales is Duke of Cornwall.

and now draws a pension of about $80,000 a year in lieu of the tax that would be paid to him from the stamping of Tin ingots. There are Tin mines in various parts of the world—Malaysia, Australia and South America. The Tin-stone is crushed, melted, fluxed and poured into blocks, ingots, pigs, etc.

How is the Tin put on our wash-basins and milk-pans?

By simple immersion, after the proper preparation, of the sheet-iron article that is to be coated with Tin. Our pins are boiled in Tin for four hours. The affinity of the Tin with the Iron molecules is so great that henceforward the utensil is practically Tin, and in this way the cost of the rarer of the two metals is economized. No other metallic composition for daily use, in which food may be prepared or fluids boiled, has found favor in America, though many kinds have been introduced.

What is the chemical value of Tin?

Very great. Solutions and Salts of Tin are widely used at the calico works as mordants, to set and beautify colors and promote the various processes. By the use of Tin compounds it has become possible to multiply the weight of silk; to give black silk the metallic weight and lustre demanded by women; to give a heavy face to calico; to use the aniline colors mixed with mordants, without the dye-vat, and practically to revolutionize the entire art of printing cloth. (See Calico.) Oxide of Tin gives a milky color to glazes in pottery, and has been used by the potters for thousands of years.

How is Tin-foil made?

By rolling the ingots into thin sheets. These sheets are cut into squares and built into blocks, to be pounded with wooden mallets like gold leaf. The leaf that was once put on the back of mirrors was made of Tin, Copper and Mercury. Speculum metal, for telescopes and spectroscopes, is made of Copper and Tin.

What vastly important use do we make of Tin?

We use it for our cans, and the term "canned goods" offers one of the defining marks of our civilization. These cans are made in millions at nearly all of our large cities.

Describe a Tin Can-Manufactory.

Plates of bluish sheet-iron, 14x20 inches, arrive from the rolling-mills and go to the store-room ; thence on trucks to the cleansing room. Here a vat of dilute Sulphuric Acid steams and fills the room with mist. The plates are washed in the sour water until they turn gray—their true color. Then they are washed in hot water. Now they go wet and steaming to hot rollers, which drive off the moisture. Other rollers and brushes daub the plates with stearin, an oil flux, which is to make the molten Tin adhere. Now the greased plate goes on a band through a vat holding 5,000 pounds of molten Tin. On its way from the Tin bath the Tin plate, now shining like a silver mirror, passes on bands through a bath of palm oil. This is to prevent cracking and blistering. The oily plate now falls into a bin of bran, which revolves, and the bran absorbs the unneeded oil. The Tin for this factory comes in seventy-five pound ingots from Australia.

How are the Tin cans made?

In die presses that move when girls touch a foot-clutch. The working tables of the machines are tilted. The cover of a baking-powder can is cut, shaped and letters embossed in its metal, all by one movement of the foot. A girl can make 10,000 covers in a day. The piece of Tin for the sides of the can is cut between steel blade-wheels, and the bent strip is crimped together ; the bottom-piece is stamped and clamped on the bent side-piece, and the whole operation is done in a few seconds, without much manipulation. The covers are put on the cans by hand. These are dry boxes for powders.

How is the soldering done?

As the cans for liquids come from the presses, they are placed sidewise on a sloping rack, many feet long. At the lower edge of this rack is a gutter of molten solder, so that as the can is rolled along its lower edge is immersed in the metal. At the end they are reversed, carried back to the starting-point, and rolled along the other end up. In the testing-machine they are immersed in water, and must send out no bubbles or they leak—as we saw in the Tomato-Cannery. (See Fruits.) In another

department cans are painted, and advertisements or labels are stenciled on them. One thousand people may be employed, and a million cans a day made.

What becomes of the Tin scraps?

They are baled, taken to the foundry and melted into weights for window-sash.

What may be said of Tin Cans?

They are the most numerous, best and cheapest utensils man has ever made, but their use is accompanied with the most astonishing waste, in all instances where they must be cut open in order to empty them. At present they cover the open lots of cities with unsightly refuse, and even to gather them and melt them into sash-weights does not seem to be feasible.

What is the Arsenic Group of Elements?

It is composed of Vanadium, Arsenic, Niobium, Antimony, Tantalum and Bismuth. Of these only Arsenic, Antimony and Bismuth especially interest the public. Nitrogen and Phosphorus, but for their overwhelming importance, would also be described in this group. Vanadium, Niobium and Tantalum are gray or black powders.

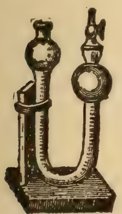


Fig. 109. MARSH'S APPARATUS for DETERMINING ARSENIC.

What is Arsenic?

The best known of our poisons, and a source of green paint and colors. The Element, Arsenic, was not isolated until the eighteenth century, but Orpiment, the yellow Sulphide of Arsenic, was known to the Greeks. What commerce calls White Arsenic is Arsenious Acid. The Element itself is a highly brittle steel-gray metal. It is mixed with lead in the making of shot, and is used in aniline dyes. The pyrotechnists use it in making Indian white fire. In dyeing, calico-printing, wall-paper staining and medicine it still has a place. As a medicine, in a highly diluted form, Arsenic improves the action of the skin, but imparts an unhealthy white look to the complexion. Arsenic is useful in glass-making, and furnishes many alloys for the improvement of Lead and Steel. With Copper it makes

the most brilliant of greens, doubly poisonous, and the public usually regards a bright green color, not made by foliage, as a sign of the presence of deadly substances. In the middle ages poisoning flourished, and the Medicis and Borgias have a sombre chapter in history with their poisoned gloves and flowers.

What is Antimony?

A very important metal that enters into many alloys, but principally our printing-types, our Britannia-ware, our Babbitt anti-friction metal for the axles of our great wheels, for stereotype plates, and for gun-metal. This Element (called Stibium by the ancients), is popularly said to have its modern name, Antimony, that is, anti-moine, anti-monk, from the story that it was administered to the occupants of a monastery as a valuable medicine and killed them all. It is a poison that acts slowly on the human system, if carefully administered, rendering the detection of the crime in former days difficult. But with modern Chemistry, that danger has passed. Antimony comes to the metal works in grayish pigs, and our Western States produce it in good quantities. It is a color for glass-making. Antimony is used in the manufacture of black lead pencils.

Did the Asiatic women use it?

Yes. The "tutty," for their eyes, was made of Antimony, and gave a lustre to those organs. Jezebel painted her eyes with this metal, probably, and the Bible often speaks of the practice, which is continued to the present day.

Has it any use in medicine?

Tartar Emetic is made of Potassium, Antimony, etc. There are many other drugs, caustics and plasters of Antimony. It is in fact a valuable remedial agent.

What is Bismuth?

It is a hard, brittle crystalline metal, closely associated with silver and gold ores, and once credited with giving a blue color, because it had not been separated from Cobalt. It was first used as an alloy in solder, and is a component of that useful

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substance. Its alloys, in other instances, are uncommonly fusible, and it is possible to mix several fairly hard metals with it so that the amalgan will melt if put in boiling water. Wooden figures may be silvered with Bismuth, and other lustres are made of it. A little Bismuth enters into many popular alloys, like Britannia ware. It is a stomach medicine. The potters use Bismuth to make the gilt braid adhere to porcelain, and as a flux it is valuable. "Pearl white," "pearl powder," and other cosmetics of this order, are usually the subnitrate of Bismuth.

What is the Tungsten Group?

Molybdenum, Tungsten and Uranium. Becquerel, of Paris, was the first to successfully study Uranium. Out of the Uranium ores came Radium, Polonium, Actinium, etc., with their Emanations. (See Index.) As Radiance and Fluorescence have advanced in daily convenience, the rare metals of this group have become matters of popular interest. One of the Sodium compounds of Uranium out of which Uranium glass is made is now manufactured on a large scale. Edison was the first to use Tungsten on the screens of his Fluoroscopes for the observation of the effects of the X ray, and for his incandescent lamps, when he discarded the Carbon filament.

What is your Last Group of Elements?

The Cerium Group—the celebrated "rare earths." But we have here used the groupings of the books, for convenience. At page 547, you may see and study Mendeléef's groupings and computations of atomic weight in logical arrangement. The Elements of the Cerium group are found in minerals like Cerite, and have been notable (especially Thorium) because of a revolutionary improvement in the methods of burning our common illuminating gas. In this group are Thorium, Cerium, Lanthanum, Didymium, Yttrium, Erbium, Neodymium, and Praseodymium. The Spectroscopists are frequently discovering new Elements that most often belong in this group. We have Terbium, discovered by Thálen, Samarium and Gadolinium, by Marignac, and Holmium and Thulium, by Soret.

What was Welsbach's discovery?

Dr. Auer von Welsbach prepared a hood for the common gas flame. Through the incandescence of this hood he vastly increased the radiation of light and at the same time economized the expenditure of gas. The hood was made of the salts of the rare earths (including Zirconium). Thorium, with a little Cerium, in the end seems to have proved to be the most efficient. A cotton hood was first soaked in solutions of the salts and the cotton burned away, leaving a white substance that could be heated to incandescence and maintained at that temperature for long periods without disintegration. The cotton soon gave place to china-grass or ramie, and this in turn made way for artificial silk, or cellulose. But the Elements used for incandescence were so rare that the Welsbach invention had no commercial value until deposits were found in Henderson County, North Carolina, and elsewhere, and the farmers of many an "oldfield" began washing out "Menacite" ore and selling it at prices that might be paid for gold washings. At present it is averred that Germany alone uses over 330,000 pounds of Thorium nitrate annually, and that Freitas, of Brazil, furnishes 120,000 pounds of this supply. In the cities the gas-mantle lights are astonishingly brilliant, cheap and dependable. In winter, too, they are conveniently warm.

What is Catalysis?

It is the name of a class of remarkable phenomena, the study of which has become highly important in the fields of Chemistry and Physiology. In Catalysis the mere presence of one chemical urges other chemicals into activity as to each other, and the disturber remains unchanged. For instance: Oxygen is a gas; so is Hydrogen. Mix these two gases and they will, as to themselves, remain in an unaltered state, like pepper and salt mixed. Introduce a thin sheet of Platinum and the gases will combine (into water) but no discernible change has taken place in the Platinum. Radio-activity may be in play.

What is an Enzyme?

An Enzyme is a catalytic substance produced from living organ-

isms. The extraordinary number of Enzymes has led to studies that have greatly advanced the commercial activities of mankind. Yeast (p. 115) is an Enzyme; rennet (p. 137) is an Enzyme. The presence of Enzymes in the human body, and their possible action, have brought the subject of Catalysis to the forefront of science.

What is an Opsonin?

An Enzyme or Catalytic in the blood, on whose presence or absence depends the willingness or unwillingness of the white corpuscles of the blood to devour and destroy bacteria. The name of an Enzyme often ends with the syllable *ase*—as hæmase, diastase, zymase. The ptylin of the saliva, the pepsin of the stomach are Enzymes and Catalytics.

What are the Brownian Movements?

The movements of microscopical bodies when suspended in a fluid, even though Life may have departed from the bodies. These motions were first described in 1827, by Robert Brown, the great naturalist of the British Museum. They are now known to be due to molecular motion, as was at first supposed.

What are Colloid Metals?

Dissolved metals. *Colloid* is from the Greek for *glue*,—viscous, cloudy, thick, etc. Professor Bredig, of Heidelberg, obtained a colloidal suspension of Platinum in pure water by getting an arc (discharge) from Platinum wires, with the poles held under the water. He used a current of ten amperes and forty volts. In this way the water is eventually deeply discolored by particles of Platinum. In theory, these particles will stay in suspension indefinitely, according to the law of gases, being less numerous as they grow in distance from the earth's center. It is found that these Colloid metals are catalytic agents of extraordinary commercial value. They are studied with the Ultra-Microscope.

What is the Ultra-Microscope?

The ingenious union of a widening of human sight and a condensation of the light used. It was invented by Seidentopf and

Zeigsmondy. A millimeter is .03937 of an inch. The best microscope they could get would detect an object 7,000 times smaller than a millimeter in length. They desired to study the colloidal metals in the glass they were making. These could not have been seen with the best microscope. They condensed the powerful beam of an arc-light into a most minute beam, and directed the tiny beam into the particles to be surveyed by the microscope. This caused the particles to light up and become visible. Bredig applied the apparatus of the Ultra-Microscope to all his colloidal suspensions and the effect on the Gold solution is thus eloquently described by Prof. Duncan: "The sight . . . is one never to be forgotten. The beautiful ruby color of the liquid is gone, and in its place is a starry night. The whole field of vision is scattered with glittering points of light, now green, now red, now yellow, and one finds one's self wondering whereabouts in these mazy configurations is the Greater Bear or the North Star." Bredig opines that each "star" contains about 200 molecules, and each "star" is rotating rapidly on its axis, so that, at last, the Brownian movement is proved to be the long-theorized whorl of the molecule, or atom.

How has the investigation of Catalysis benefited the Medical World?

Catalysis has become a leading thought of physicians, and care of the diet has increased. The functions of obscure glands of the body have become important studies. Why certain persons can not eat certain foods with benefit, now offers clues to diagnosis not possible before. Drunkenness and the lesser effects of alcohol are caused by catalytic action. The puzzling effects (philosophically) of potatoes as food are catalytic. There is no limit to this branch of the subject.

How as to Industrialism?

Catalysis is a time-saver, and the catalytic agent does its work free—you eat your apple, and have it too. It is as yet (philosophically) a miracle—magic. All the processes of making the great Sulphuric Acid (p. 362) are and have been catalytic, but tend toward greater simplicity, the materials (iron pyrites, water

and air) being as cheap as the maker could wish. Here the oxide of Iron is the catalytic agent. Artificial indigo is displacing the natural product, and Mercury and other metals are the catalytic agents. The photographers are securing wonderful results with catalytics. In the making of the new and admirable dyes from coal-tar, the Copper compounds do their service freely and instantaneously. The innumerable industrial catalytics have extended from the metals into Iodine, Carbon, and the Enzymes, and the latter now even serve gratuitously as aids in making our soap.

What further do we learn about Molecular Motion?

Mr. J. Perrin, of Paris, is not so clear in seeing the whorl of the particle in the solution as is Bredig, and describes the Brownian movement as more of a trembling like the moon's libration; but he believes that this disturbance of the particle in suspension actually proves the molecular movement of the water. The particles reveal the internal agitation of the water with more exactness as they are smaller, "just as a cork follows the motion of the waves better than a large ship." Perrin says: "By measuring the density, the radius, and the concentration of the suspended particles at various points, the laws of gases give us the number of molecules in unit weight. It is remarkable that, by this indirect method, we obtain for this number 68 followed by 22 ciphers, while the theory of gases gives 60 followed by 22 ciphers." Other methods reveal the same order of dimension, and we may now know (with much the same proofs that we have that there is air about us) that fluids move incessantly. The same perpetual motion that we see in the Universe beyond us, goes on in air, water, earth. Fire is one of its visible expressions.

What is Thomson's Spectral Analysis?

Sir J. J. Thomson has recently discovered that he can obtain a photograph of rays cast by burning elements. These photographs will identify the element, if known, and will fix the atomic weight, whether the element be known or unknown. By means of the Crookes tube, proceeding somewhat as with the X ray, the positive rays are sent through a tube at the cathode, and there deflected by both magnetism and electricity. The rays then are registered

on the photographic plate, and resemble vegetable growths, such as tubers, but different for each Element—or, with a differently curved sprout for each Element. By the curve of these photographic lines or "sprouts," the atomic weight is known. The spectra of the Carbon oxides are easily told apart. The discoverer exhibits photographs of the spectra of Nitrogen taken from the atmosphere and Nitrogen isolated by the chemist. The atmospheric Nitrogen shows a line whose curve registers an Element weighing 38 Hydrogens (Mendeléef). The other spectrum has no such line. Thus Thomson knows at once that the line in the atmospheric Nitrogen is made by Argon. The advantage claimed for the new spectrum over the old one is that the new one gives the atomic weight of the Element, and therefore its rank in the chemical scale and approximately its special characteristics.

☞ **See note concerning new Elements on page 223, and the last chapter, entitled the Advance of Science, page 544.**

Sugar, Etc.

What is Sugar? (See Chemistry.)

It is a differing but peculiar combination of carbon, hydrogen and oxygen. These are three of the four physical necessities of the life-movement. Our most suitable food will therefore abound in Sugar—as in bread and milk. The fourth substance (not present in Sugar) is nitrogen, which we obtain largely in air, meat and cheese.

Whence do our table Sugar and our table sweets come?

From sugar cane, beets, sorghum, palms, corn, grapes, maple-trees, honey and other substances—principally from sugar-cane and beets. By far the greater part of our Sugar is imported largely from the West Indies. The Government has at times offered a bounty to the Sugar producers of Louisiana, and whether or not this bounty should be paid, or the import taxes on Sugar be abolished, has been a question of national politics at several elections.

What is Sugar Cane?

It is a plant much like corn, but rising to a height sometimes of twenty feet. It grew originally in the far East, and must have a hot, moist climate, thereby differing from corn. It was brought to Europe by the Moors, who called it the honey-bearing Indian reed, and started plantations in Spain and Sicily. The Spanish sailors took the plant to the Azores, Madeiras, Canaries and Cape Verd Islands, and onward to the West Indies and Brazil. Spain and Portugal long enjoyed the Sugar trade of the world.

Where did the Ancients get Sugar?

They probably used honey. At least there are many classical recipes extant showing that honey was used in cooking. There

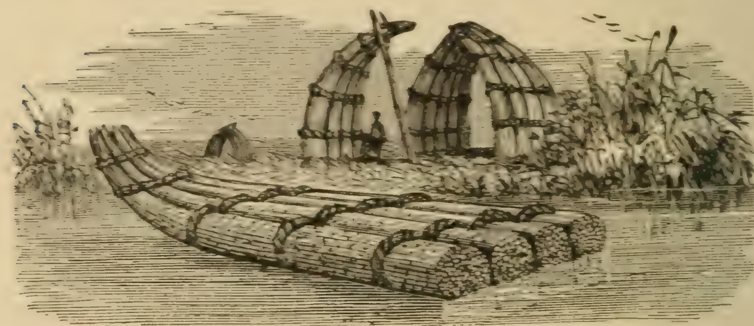


Fig. 112. SUGAR CANE AFLOAT.

are about fifty references to honey in the Bible, but Isaiah also refers to Sugar-cane (chapter 43). Honey served for Sugar in the middle ages, as our libraries show. It was understood that the first Sugar refinery of the western world was established at Venice. When loaf-Sugar was brought to England, it was used in making presents to Kings and great personages. The sale of loaf-Sugar has now been abandoned in commerce.

How is Sugar classified?

In two chemical families—the Saccharoses and the Glucoses. Early in the nineteenth century Gay-Lussac determined that the molecules of a Saccharose were each made of twelve atoms of carbon, twenty-two atoms of hydrogen and eleven atoms of oxygen. Later, Dumas and other chemists assumed that Glucose was composed of molecules made of six atoms of carbon, with twelve atoms of hydrogen and six atoms of oxygen. It is understood that with the addition of sulphur and nitrogen the German chemists have produced compounds a thousand times sweeter than Saccharose.

Has chemical knowledge prospered?

Yes Under the influence of commercial necessity, the nature

of Sugar, the philosophy of crystallization—that is, how molecules form together in one of their solid states—and other secrets of nature, have been vigilantly studied.

What are the sources of our commercial Sugar?

First, from Sugar-Cane; next, from Sugar-Beets; next, from starch; next, from maple-trees. Then come sorghum cane, palm trees, grapes and other inconsequential products.

Can Sugar be made artificially by the Chemists?

Generally speaking, no. From a theoretical point of view, there is much to be learned. Foreign atoms cling tenaciously to the molecules of Sugar naturally produced, and only the costly processes of filtration or solution by water will separate the good from the bad. If the scientists could themselves compound a Sugar molecule, the price of Sugar could be cheapened indefinitely.

Describe Sugar-making from cane?

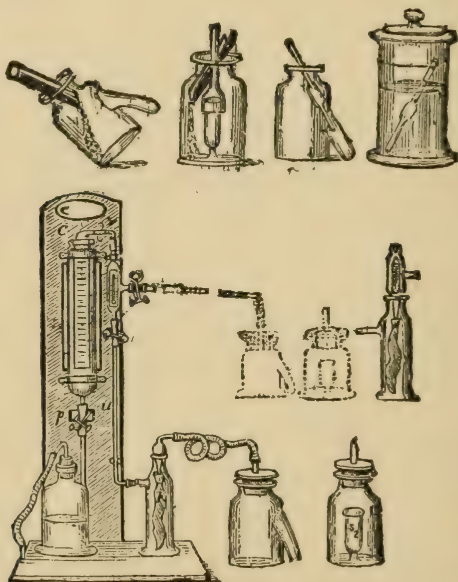
The long canes go to the crushing rollers on a feed belt. Sometimes the head-stocks of the top-roller have a hydraulic accumulator or "spring," which regulates the pressure and guards against the dangers of an uneven feed. There are different arrangements of rollers, but generally a top, a cane and a megass or bagasse roller make the first set. The top-roller is midway above the other two. After the cane enters between the top and the cane rollers it is sent upward by a trash-turner into the bite between the top and the megass rollers. In Lousiana another pair of rollers lies beyond. When the trash or bagasse comes from the last set of rollers it may be burned under the boilers after a little drying.

What becomes of the juice?

This green, sticky liquid goes in troughs to a strainer, and thence to a vat. Fermentation begins at once. To remove or neutralize the acids, milk of lime (lime and water) may be added and heat applied, or the juice may be passed through the fumes of burning sulphur. Phosphoric acid is sometimes used.

Describe the lime process.

The juice goes into clarifiers, that is, iron kettles holding five hundred gallons. Milk of lime is added to the warm juice, and the heat is further raised to less than two hundred and twelve degrees. A thick scum rises, and thus what is called the defecation of the juice is effected. In the new system, there are series



Ffg. 113. APPARATUS FOR MEASURING CALCUIM IN SUGAR.

of four clarifying cauldrons, heated by steam coils. The scum is composed of thickened albuminoids, lime and other substances.

What is the Saccharameter?

It is a gravity-tube, which may be set afloat in the boiling cane juice. By specific gravity the density of the Sugar-juice may be gauged on the scale that projects out of the liquid. These sacchrameters are used at each cauldron. (See Milk.) The scum is made into rum.

What is the Vacuum-Pan?

It is the vessel into which the clarified juice flows. It is a vacuum, but not a pan, for the vessel is spherical, with copper steam coils in the bottom. A glass window permits the liquid to be seen, and electric lights make the interior still more plainly visible. An air-pump and condenser remove the air, and the juice boils with less heat than two hundred and twelve degrees and with more agitation than in the open air. When the molecules of Sugar begin to form into crystals, the charge is dumped into the mixer.

What is the Mixer?

It is a long trough, in which a shaft revolves. On the shaft are steel arms that play in the Sugar, beating the crystals apart, and bringing them near other molecules still unattached. When the grain or crystal is of the right size it goes to the centrifrugal.

What is the centifrugal machine?

The principle is the same as in the cream-separator and the flour mill. A kettle-shaped vessel in which the wet sugar is placed, revolves twelve hundred times a minute. Its sides are

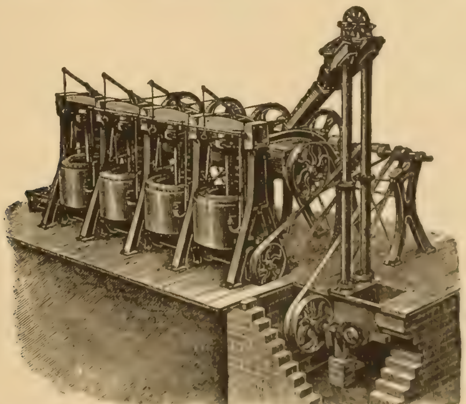


Fig 114. CENTRIFUGAL SUGAR MACHINES.

lined with brass gauze. The thin parts of the Sugar are heaviest, and they fly upward to the gauze, and outward in the form of molasses. Remaining in the kettle is dry, white Sugar, which

is the sweet Coffee A of our tables. It is a better Sugar in many respects, but does not compete with the popular granulated Sugar of the great refineries.

Describe the Sugar Refineries.

Hogsheads of *Muscovado* (word from the same root as *Mischief*), meaning unripe or unfit Sugar together with molasses, arrive in vast quantities. The material goes to the top floor, where it is dissolved in water and boiled in pans or "blow-ups"

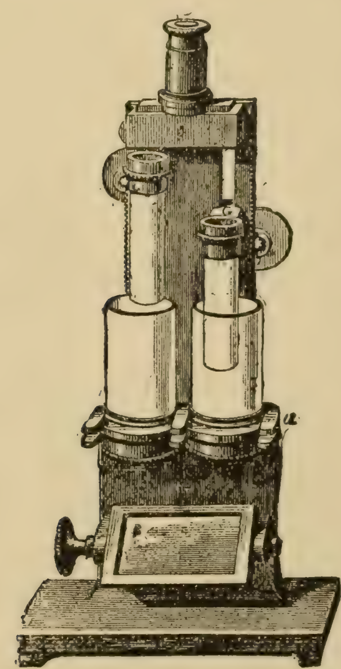


Fig. 115. DUBOSC-SOLIEL'S APPARATUS FOR COLOR ANALYSIS OF SUGAR.

with steam coils. From these pans or "blow-ups" the sirup passes through from fifty to two hundred cloth filters heated by steam. These hot bags retain many impurities, but do not remove the yellow color. Now the real refining begins.

Describe the Filters.

They are iron cylinders fifty feet high, resembling the generators in the Vinegar Factory. They are filled with animal charcoal, or bone black. After traveling through fifty feet of bone black, the sirup comes out in molecules free of all substances, except carbon, hydrogen and oxygen in the Saccharose proportions. The sirup may now be treated as it was at the cane mill, or it may be run into innumerable small molds standing in rows. Its crystals are larger, have a higher glaze, possess greater adhesive power among themselves, and the Sugar may be cut into small blocks of various shapes and dimensions, or crushed into separate crystals that thereafter make no attempt to cohere, and show but little affinity for water and none at all for alcohol.

How is Granulated Sugar made?

To make it, Coffee A Sugar is dried in a revolving cylinder.

How is Pulverized Sugar made?

Dry Sugar is ground in stone buhrs or steel rollers, and sifted like flour.

What has cheapened the price of Sugar?

First, the use of steam pipes for heating. Second, the use of the vacuum-method, which saves fuel and hastens the action. Third, the bone-black filters. Lastly, the most important improvement was the use of the centrifugal machine, which reduced the time for refining soft Sugars from two weeks to a day, and enormously reduced the cost.

Is the refining interest a large one?

Yes. One company has a capital stock of $100,000,000, and pays dividends on this sum at the rate of as high as twelve per cent. per annum. One of the establishments of this company—the largest refinery in the world—covers five city blocks on the East River, in Brooklyn.

How is competition carried on against this Company?

By means of importation from foreign countries, where a bounty is practically paid through the rebate of internal taxes.

Is Sugar adulterated?

The chemist will naturally strive to add the free elements of

air to carbon, and to give to Sugar bulk with the least expenditure of sweetness. Sugar betraying alkali, ammonia or sulphur

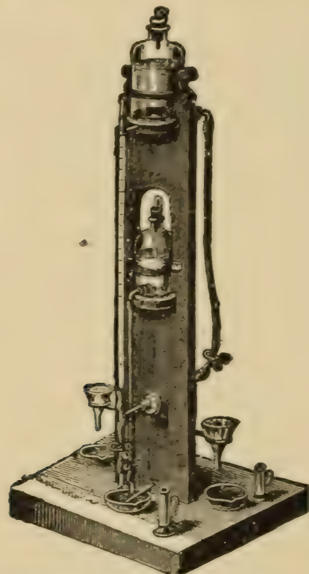


Fig. 116. APPARATUS FOR FINDING THE ALKALINITY OF SUGAR.

by its taste or smell—particularly the latter—should be rejected. In the vast field of carbon compounds, where molecules are often nearly alike, the eye, the nose and the tongue are as cunning as the most learned chemist.

What is Diffusion, or Dialysis?

This is the method by which the Sugar molecules are taken from beets, and Sugar-cane may be treated in the same manner. We will suppose a thin curtain, like the wall of the vegetable cell. Now, if two liquids of a different degree of density are separated by this wall, they will diffuse through the wall and establish an equilibrium of solution. This is a form of Dialysis. If a cell full of Sugar juice holding twelve per cent. of Sugar be placed near an equal quantity of water, the two chambers would soon hold six per cent. of Sugar. Put the six per cent. solution

near another twelve per cent. solution, and all would become nine per cent. Again, and the outside solution would rise to 10.5 per cent, or within 1.5 of the full capacity. On this theory all the Beet Sugar is made.

Apply the Diffusion theory.

Tall, upright cylinders will be filled with clean sliced roots. The contents of each will weigh two or three tons. Eight of these cylinders stand in a series; while two or four others are out of service, getting ready to take places in the active series. Pure water flows into cylinder No. 1, which has been longest in operation, and has the least Sugar remaining in the cells of the beets. When No. 1 is practically exhausted of Saccharose, it is disconnected and No. 2 becomes No. 1, while the fresh cylinder becomes No. 8. The water goes from cylinder to cylinder, acquiring sweetness as it goes. Before it is urged into the last cylinder it is heated, and passes under pressure among the fresh beets, becoming thick and rich with sugar—in fact, the water that comes from No. 8 is fifty per cent. Sugar, and is free of the nitrogen, fibrine, sulphur, potash, sodium and calcium that are the especial results of any crushing or macerating process. When Sugar-cane is diffused, the stalks must be cut into slices, and, as fermentation is rapid, there are many difficulties. But no Sugar-juice yet secured is in molecules of Sugar and water. Other atoms are always present, showing obstinate affinity, and the beet Sugar molecules are more difficult than the cane molecules. The Germans have usually been forced to use the expensive "charcoal" filter even in the raw stage, thus making two filterings of this kind. The other parts of the process are such as we have already described, except that carbonic acid and barytes are also used for clarifying.

Did the German method serve as an example?

Yes. Great factories were established in California, Nebraska, Utah and Virginia, and the product of thousands of acres is turned into Sugar. Millions of capital are employed in these institutions. A ton of beets furnishes two hundred and eighty pounds of pure Sugar.

Describe a typical American Factory.

Mills and sheds closely connected surround a tall chimney. A field is filled with large boxes or trenches, into which the farmers shovel their wagon-loads of beets. The large trench or box, is bottomed with loose boards, and under the boards is a cemented or paved flume for running water. When the beets

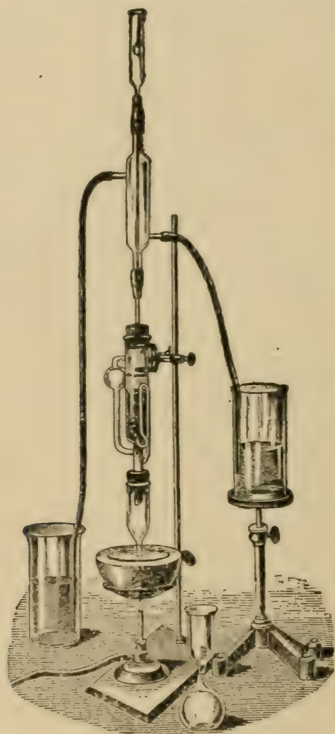


Fig. 117. SZOMBATHY'S APPARATUS FOR DETERMINING THE SUGAR IN BEETS.

are not wanted, they are covered with straw or soil, in silo fashion. The problem of correct preservation has not yet been solved, as there is danger both from sweating and freezing. The beets now lie in the upper trench as they came from the farm. Of course some soil adheres to them.

SUGAR PLANTATION—MATTO GROSSO.

Fig. 111. SUGAR, FROM CANE TO HOGSHEAD.

What happens next?

Warm waste water is let into the under-ditch or flume, and this lifts the loose boards. The beets fall down and go toward the factory. At the factory they fall into buckets on the rim of a wheel and are carried into the washing-augur, which revolves in an iron trough. As the beets are forced along they become clean. At the end of the trough they fall into buckets and ascend to the top of the building, drying as they go. Arriving at the top, the beets fall into an automatic weigher, which tips at half a ton, registers and drops its half ton into the slicer.

Describe the Slicer.

It is on the floor just above the diffusion battery, which is itself copied after the system of iron cylinders described on the previous page. The slicer is a large revolving disk, on which are knives of curious shape. These revolve under the mass of beets and cut them into flakes three-sixteenths of an inch thick. In our factories the battery of diffusers stands in a circle, so that a revolving chute from the slicer can fill any one of the cylinders. The beet juice that comes from the last of the diffusers is chocolate-colored.

What becomes of the slices?

They are dropped from cylinder No. 1 into augur presses and reduced to pulp. The pulp, partly dried, is sold for cattle-feed.

What is Molasses?

It is the residue of Sugar molecules that refuse to arrange themselves in crystals. It is not without crystals, and they may be secured by further treatment, which usually is carried on for two or three processes after the first yield of Sugar. But the Sugar molecule has various properties. A ray of light sent through a molecule that will crystallize turns the ray one way, and this is called *dextrine* or right Sugar. A ray through another molecule turns it to the left—called *lævo-rotatory* Sugar (from *læva*, Latin for the *left hand*, as *dextera* is the *right hand)*. The left-handed Sugar is also called *invert Sugar*. Glucose is lævo-rotatory. Cane Sugar yields both *dextrose* and

lævulose. Sugar is tested by making it into a solution with

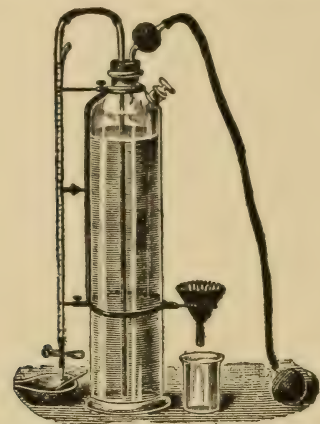


Fig. 119. APPARATUS FOR THE EXACT ANALYSIS OF SIRUPS AND MOLASSES

water and viewing it with the polariscope. The light, as we have said, is polarized differently.

What is Polarization?

We can best answer by asking you to hold your right hand before a mirror. You will recognize it as your left hand. Something has happened to the rays of light that went from your hand to the mirror and now come out again. They invert, or turn your right hand into a left hand. They have changed

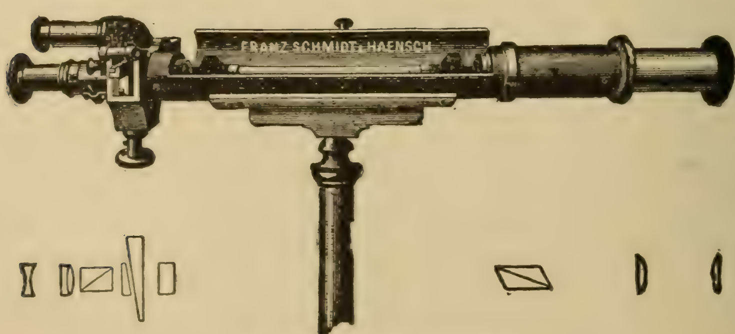


Fig. 120. THE POLARISCOPE.

the poles of direction. By the varying action of the Sugar molecules on a ray of light in a similar way, the quality of the Sugar in the solution of Sugar and water is determined, as certain molecules produce the best Sugar, and certain other molecules the poorest, etc. And as we have said, the vast financial interests involved have encouraged chemical research. The Dutch set the standards that are in use as to the quantity of Sugar solution, angle of light, etc.

Is there a difference between Molasses and Sirup?

Yes. The residue from the first making of Sugar is called Molasses. The residue from the refineries is Sirup. The "golden drips" or Sirup is Invert Sugar separated from all foreign substances, and is probably composed of molecules containing six carbons, twelve hydrogens and six oxygens—that is, Glucose — and other molecules containing twelve carbons, twenty-two hydrogens and eleven oxygens — that is Saccharose. But these molecules refuse to immediately coalesce into crystals.

Describe the Sugar Crystal?

You may study it in any piece of rock candy, where you will see the form which pure Saccharose must assume. The crystal is called a monoclinic—that is, it has one intersection, and that inclines. It is not hygroscopic—that is, it will not attract moisture to its surface, like glass. It is scientifically called a rhomboidal prism, but it may be more clearly described as a nearly square tabular formation with sloping edges. A deep groove (the "intersection") divides it in two parts. If broken in the dark the hard crystal will give a bluish flash.

What is the product of a Sugar Beet Factory?

It may be thirty tons a day or more. The operation is usually continuous, running night and day and Sundays. There is a laboratory for chemical tests. Whether it be crystallized Sugar, Sugar juice, or beets that are to be tested, the article is reduced to a solution in water, clarified if necessary, and submitted to the Polariscope, to find in what direction and at what angle a ray of light is turned by the molecules in the solution. Cattle-feed, ashes, coke, limestone, coal—all things used or made in

the factory—are undergoing daily and repeated tests, to ascertain their molecular condition, and therefore their true value.

What Beet is used?

The *Beta maritima*, a mangold, or mangel-wurzel. The success of the diffusion process has dealt a blow to the cane plantations of the tropics, and it is not impossible that the United States may eventually produce all the Sugar which is consumed within the national borders.

What is Maple Sugar?

It is an American product, which was made by the Indians before Columbus discovered America. It is known by a peculiar taste, generally liked by Americans, but disliked in Europe. It is the residue of boiled sap from the Sugar maple—*acer saccharinum.* This sap is very weak in Sugar, and over 97 per cent. of water must be evaporated. The process is still primitive, although vast quantities of Sugar, estimated at over fifty million pounds, are annually made. It is possible that with refining and filtration, the pure crystal of Saccharose could be obtained, but this would destroy the essential characteristic of Maple Sugar, and damage the market.

Describe a Sugar Bush or Camp.

The trees are tapped with one spout, driven in on the sunny side. Snow is still on the ground. The sap runs best while the sun shines. Wooden troughs stand under the trees to catch the sap, and big iron kettles are hung over roaring forest fires that burn all night, frequently with merry-making. From the deep kettles the sirup passes to pans, and thence to tubs, where sediment may settle, particularly the malate of lime, called by the farmers "Sugar-sand." Malic acid is the essential principle of apples. After settling, the sirup goes again to pans, and soon after it boils it is ready to granulate. It is now poured into moulds and on cooling, has formed a compact body.

What is Maple Sirup?

It may be made by leaving the original water in the product, or by adding the proper quantity to the Sugar. The latter way saves freight. Naturally, the compounding of maple sirup in

the large cities has led to the introduction of adulteratives, until the people have come to regard city sirup as certain to contain Glucose. But reliable dealers—that is, merchants of recognized commercial standing—are especially averse to these unfair practices.

What is Glucose?

Glucose, once called Glycose, is one of the two Sugars. It has six atoms of carbon, twelve of hydrogen and six of oxygen in each molecule. In its commercial form it has not been permitted to crystallize, and is a thick, glassy, light-colored sirup. If it has been crystallized, it goes under the name of "Grape Sugar." Enormous factories, twelve stories high, covering wide areas of ground, are devoted to its manufacture.

What is Glucose good for?

It is one of the most serviceable substitutes ever discovered by the adulterators, hence the unfavorable notoriety which it has obtained. But it is in itself a valuable though inferior Sugar. It serves equally well with Sugar as a preservative, hence may take the place of Saccharose in all preserves of fruit. Its use in candy is objectionable, but all the cheaper grades of candy are probably thus made. One of its principal uses is as common alcohol, into which it may be easily converted. This alcohol may be put in wine, beer, other liquors, or it may be oxidized into vinegar, as we have seen.

What is Glucose made from?

From starch. The starch is made from corn, and we have described the process under the head of Corn. But after the grinding of the corn-mash and the separation of the germs and the gluten, the remaining starch goes with water to the converters. The converter is a great closed copper boiler, into which steam pipes lead. These steam pipes are perforated, so that the live steam is injected into the starch-water at a pressure of forty pounds. About twenty-five pounds of muriatic or sulphuric acid are added for one thousand pounds of Glucose. The heating occupies about an hour. The starch has now been converted into Glucose.

What is the supposed molecule of Starch?

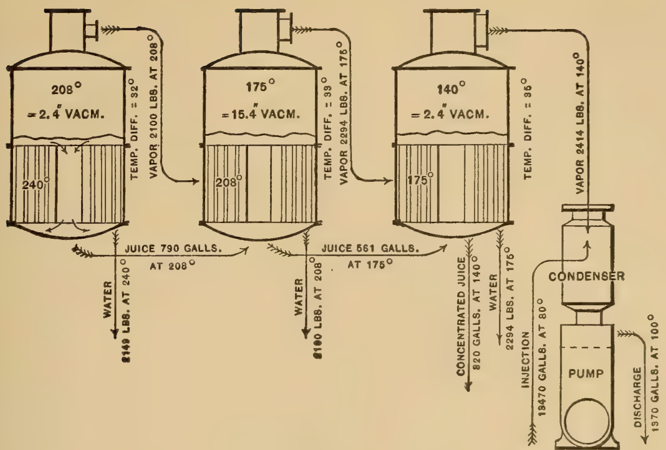
It is formed of thirty-six atoms of carbon, sixty-two atoms of hydrogen, and thirty-one atoms of oxygen. To this molecule there cling twelve molecules of water, each molecule of water having two atoms of Hydrogen and one of Oxygen. The heat and the acid have disrupted the starch molecules, and they have formed into the easiest combinations, which are or seem to be Sugar combinations, the water molecules joining the water in the solution and leaving the carbon atoms. The acid molecules are still present in the solution.

What is a Neutralizer?

The neutralizing tank receives the Glucose sirup out of the converter. If muriatic acid were used in the converter, then soda is now added. Muriatic acid was named from sea salt before it was known that chlorine gas was its principal part It is hydrochloric acid, and has a wonderful affinity for sodium or its compounds. (See Salt.) The soda therefore seizes all the hydrochloric-acid molecules. If sulphuric acid were used in the converters, marble-dust is added and the calcium molecules in the marble-dust attack the sulphur molecules. These molecules are now to be strained away through canvas bags, as in the sugar refineries, or in filter-presses. The Glucose comes out as "bag liquor" or "press liquor," according to the process. It is still yellow-colored, and has many atoms of sulphur, calcium, potash, sodium and other undesired Elements clinging to its molecules. It still is in a solution of 70 per cent. water. It now goes on the bone charcoal filters, which are not half so high as those in the big sugar refineries. The fluid percolates through twenty feet of bone dust, and comes out "light liquor."

Is it now boiled?

Yes, in vacuum-kettles, like cane juice. A system of three kettles is in use, called a triple-effect, which utilizes steam that once went to waste. After it leaves the triple kettles it is 60 per cent. Sugar.



Fig, 120. TRIPLE EFFECT EVAPORATION.

Is there another filtration?

Yes. "Light liquor" is not commercially pure enough. It must again percolate through the charred bone. After this the sirup goes to the final pans, and comes off as 41, 42, 43, 44 Glucose, according to its gravity. As an adulterant it is desired in its thinnest grade.

Suppose it be concentrated and crystallized?

It is then Grape Sugar, which is used by the brewers and wine-sophisticators. Grape Sugar may also be mixed with cane Sugar. As Glucose is made from starch, it follows that in countries where starch is produced cheaper from potatoes than from corn, as in Germany, potato-starch furnishes the material.

Is Sugar made from Milk?

Yes. The Swiss dairies secure Sugar as a bye-product in the manufacture of cheese. It passes into the whey, and is extracted by evaporation and crystallization. The molecule is a Saccharose molecule with one water molecule clinging to it. This makes milk Sugar less sweet than Saccharose. A solution of milk Sugar and water does not soon become sirupy. The homeopathists use milk Sugar by preference as a vehicle in which to administer their dry medicines, and the small pills of all kinds that have become so familiar have usually been compounded in Swiss Sugar.

What is Sorghum?

Sorghum was called Guinea corn and Chinese Sugar-cane. It is a millet. Along in the '50's it was believed that Sorghum would be generally cultivated in America, and the civil war encouraged widespread attempts on the part of the northern farmers to produce molasses from this plant. It very closely resembles corn, and grows easily in all corn countries. But Sorghum molasses was not liked by the people, and the product became less after the civil war ended, and the price of better Sugar and sirup fell to a peace basis.

What is Rock Candy?

It is a collection of the crystals of Saccharose. It is used by the ton in the making of patent medicines, by liquor dealers and by druggists. It once was a popular confection. Only the best granulated refined Sugar will serve the Rock Candy manufacturer's purpose. Four or five barrels of the Sugar are emptied into a closed copper boiler, jacketed with steam pipes, and a thick sirup is made in a half hour. This sirup is poured into copper-pots, which are twice as wide at top as at bottom.

Describe these crystallizing-pots.

Across the interior of the pots cotton cords are strung in goodly number, all the way up. The cords run through holes in the sides of the pot, and the holes are battened with plaster-of-paris, which holds the cords and stops all leakage. The pots each contain five gallons of sirup. They now go to the hot house, to stand on shelves for three days. The hot house is kept at 160 degrees above zero. The crystals form on the strings and on the sides of the pot, and finally they form a crust on the surface of the sirup.

Is any Sirup left?

Yes. The sirup is drained off and sold at the soda fountains, saloons and drug-stores. It is Simple Sirup. After the sirup is drained away, the candy is washed with water and dried in a temperature of 70 degrees. In drying, the pot stands upside down over a trough. When the candy is fully glazed, the plaster-of-paris is removed from the outside, the strings drop

down, the pot is struck smartly with a mallet, and the candy falls in a mass on the packing board. It is now weighed and packed for market in five and forty pound boxes.

Is Rock Candy colored?

Yes. Carmine is added in red rock, and this is the only rock candy that is not pure Saccharose. Yellow rock is colored with burnt sugar. The manufacture of the coloring matter is a disagreeable and unhealthy operation, owing to the smoke. The workmen wear respirators.

What is Caramel?

The word is corrupted from the Latin for honey-cane (*canna mellis*). Sugar becomes caramel at 400 degrees of heat—that is, it burns. Burnt sugar was needed for coloring, in rock candy, for brandy, etc. About 1865, the word began to be used in America for a confection that was midway between a hard or granulated candy and a sirup. Caramels, as we know them, are made by boiling cream or concentrated milk, sugar and chocolate, and it is chocolate rather than burnt Sugar that gives the dark caramels their characteristic color. The mass is poured on a marble slab, cut in small squares, and wrapped by girls. An expert girl can wrap eight thousand caramels in paraffine paper in a day.

How are small Candies molded?

In corn starch. Corn starch is packed in shallow boxes. A press holding many dies descends on the starch and leaves the rows of molds. One factory may use twenty-five thousand of these boxes. The cream candy is run into the molds. Even the soft Marshmallows are thus cast. Starch is used at all stages, also as a powder to facilitate manipulation. The starch molds holding their candies, go to the "starch-buck," which breaks away the mold, lets the starch through vibrating sieves, carries the candies past brushes, and leaves them free of starch.

How are Gum-Drops made?

They may be cast from Glucose and starch. Such are the cheapest. They are made from pure Sugar and gum arabic. These are costly. After coming from the "starch-buck," both

kinds are rolled in granulated Sugar. This gives them their rough appearance.

How are Lozenges made?

Candy of this description is stamped out of cold sugar, and all other forms are made by boiling in water, or other fluid mixtures. Of course, other material, such as flour, starch, or even terra alba, may be mixed with the flour. The taste will usually determine the value of a candy lozenge. A rubber stamp is inked with cochineal, and a motto may be imprinted on the lozenge after it is made.

How are small Polished Candies made?

They may or may not have a nut or seed inside. The Sugar may be deposited on the nut or seed by crystallization, or by dipping. When the candies are of the right size, they are placed in a copper pan which revolves rapidly. The centrifrugal motion polishes and rounds the pieces.

How is Chocolate used?

It may be ground on the premises, or bought in ten-pound cakes from the chocolate factories which we have described. (See Coffee, etc.) The cream candy, cast in a corn-starch mold, may be dipped by machinery in a bath of chocolate and hot water, and carried on an endless belt through a long drying room. Or a girl may have before her a small kettle of hot chocolate, tilted on a steam coil. She places a candy on a wire spoon and dips it in the chocolate. The wet chocolate-drop is then placed on an oil-cloth in the drying frame. A girl sometimes dips three thousand drops in a day.

How is the costly "French Candy" made?

The best pulverized Sugar is used. Almonds and filberts are ground into paste. The paste may be mixed with cold Sugar. Pure cream may be used in the hot Sugar solution. A core of nut-paste may be dipped to the needed size, and the final dippings may be in colored solutions of various hues. Cochineal is added for the reds; indigo for the blues; gamboge and flowers for the yellows; and green leaves from spinach and other vege-

tables, for the greens. The darker colors are usually chocolates and burnt sugars.

How are Cocoa-Nuts used?

They enter the factory whole. The meat is extracted, cut up and boiled in a kettle with rotating dashers. Sugar is added. After cooking, like candy, the mass is rolled on a marble slab and made into small biscuits. These are browned in an oven. The mass may be molded and then cut up in strips. This candy is highly nutritious, but difficult to preserve in good condition.

Life.

What three cardinal things may be named in the Universe?

Motion (Light and Heat), Matter and Life. All these are different, yet Motion and Life are somewhat alike in nature.

Wherein does Life differ from Motion?

Life is a Motion that is eccentric, jerky or suspended. It has no regularity or period. If we see a speck of Life in a drop of water, it may go here or there, or it may stand still.

Of what is that Speck composed?

Beside the Life it has, it is an untheorized compound of carbon, hydrogen, oxygen and nitrogen, like other carbon compounds whose molecules are as yet too complicated in structure to adjust to any theory of formation yet offered.

When this compound moves with Life what is it called?

Bioplasm. The chemists cannot make it. It is the chemical and living result of other living processes that have preceded it in life.

What surroundings are necessary to this Bioplasm?

Light, Heat, Electricity, moisture, etc. All may be present, however, and death may still result.

What does nature do with Bioplasm?

In greater or less quantities it forms the vegetable and animal growths of the world. It may exist alone in one small, original mass, frequently doubling, or it may exist with millions of similar masses, and all in association with hard or soft structure formed from the masses of its forerunners or fellows.

What does the microscope show?

The commonest and easiest sight, and the most instructive, is secured by obtaining water under a green scum in a pond and putting it in the "aquarium" of the microscope. An animal called a *Rotifer*, with a bell-shaped body or mouth and long tail, will come into the field of the glass and fasten his long and sometimes spiral tail on the trunk of the twig—the scum-matter. Then he will start wheels of hair (cilia) going around his mouth and a vortex of water will suck monads or smaller animals into his paunch. The scene is marvelous, and offers to the mind some estimation of the small division into which the molecules of water must themselves be carried. The *Rotifer* divides into two animals.

What is his body made of?

Apparently a glass or mica-like substance. The gizzard or stomach may be a green color, from the scum-matter. This animal will swallow another Rotifer by error, and throw it out at once. In his early and glass-like state, this animal is a hydro-carbon compound, endowed with Life.

Name a still lower form of matter in which Life acts.

In the Amœba. This is a small, jelly-like Bioplasm, which does not retain the same shape for two successive minutes. It obtains its food by flowing around it; lays hold of its food without members, swallows without a mouth, digests without a stomach. It moves without muscles. The separation of any fragment of this jelly originates another independent Living creature.

What is seen in Frog's blood?

Movement of white blood cells that follow the characteristics of the Amœba. They seek holes in the blood-vessels, wander through and fasten upon the tissues, either to feed, or be fed to, the cells that they reach. Or the cell may seek a structure, and become a part of that structure, such as bone, hair, or nail, when it ceases to have Life. Animals usually consume plants; yet there are plants that eat animals.

Summarize, then, your remarks on Life.

If molecules of chlorine and sodium come together under certain conditions, there is agitation, condensation, perhaps explosion, and salt results. These new molecules undoubtedly remain in a state of movement, but it is of a stated kind. Again, we may compose a hydro-carbon compound that will resemble Bioplasm. Its molecules move, but with law. Now, a similarly-appearing hydro-carbon compound called an Amœba moves, but without law. It may move in opposition to heat and cold, or with them. The molecular movement of Living bodies can not, at present, be theorized. That fact is Life.

Photography.*

What is Photography?

Photography is a development of man's studies of tanning in the sun. Probably the chief thing that happens when Light shines on an Element or a compound is the union of more Oxygen with the object shone on.

Why do we say Camera Obscura?

Because, when John Baptist Porta, a scientist of Naples, brought a portable "dark chamber" to the attention of the learned, Latin was the common way of writing. He was born in 1538. The Dark Chamber (*camera obscura*) was used by Newton in studying Light.

Who was the first man to take a photograph with a camera?

Joseph Nicéphore Niepce, of Chalons, France, in 1814. He discovered the great principle of dissolving away the chemicals not acted on by the sun. Daguerre was the partner of Niepce's son Isidore. Niepce preferred copper plates.

When was glass used?

It is alleged that the first photograph ever taken on glass, dating from 1839, is now at the Victoria and Albert Museum in South Kensington, London.

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*Passing references have been made to Photography in the articles on Electricity Spectroscope, Chemistry, etc.

When were colors secured?

Becquerel (of the Becquerel rays, p. 223) photographed the solar spectrum in colors in 1842.

Has the Microscope been attached?

It was made use of by the photographers at an early date. Of late the spectacles shown to the public, such as the circulation of living frog's blood, the rotifers, and the bacteria, have been thrown on the screen by the cinematographe and added to "variety programmes," greatly to the instruction of the people. (See illustration.)

Will the Cinematographe popularize Science?

It will at least multiply scientists. Prof. R. W. Wood, by this means, shows on the screen the photographs of a single sound wave impelled by "a spark of Electricity" and rendered visible in all its movements by succeeding illuminations by electric sparks.

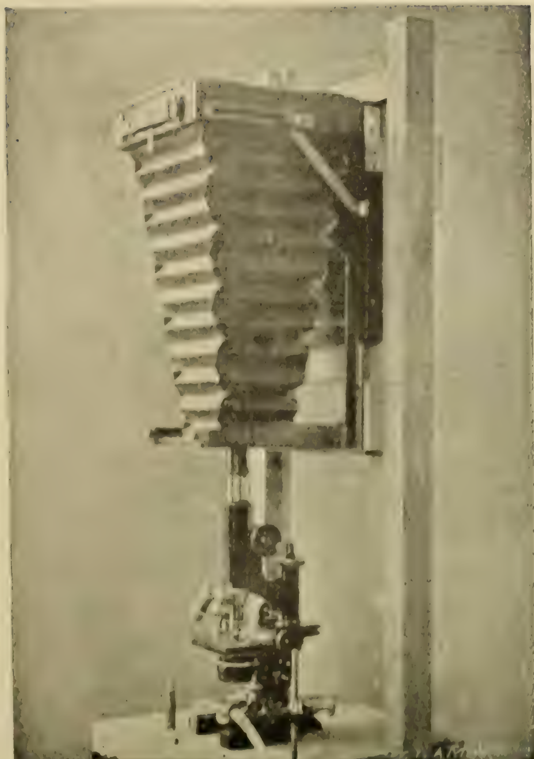
What is this rapid Photography called?

Chronophotography. In 1873 Janssen, of Paris, with his "astronomical revolver," a circular plate moving on its center, took seventeen pictures, each one in seventy seconds. In 1878 Muybridge, at San Francisco, set twenty-four cameras along a horse-race track. The horse broke wires and worked the cameras as he passed. In this way man, in a photograph, for the first time saw a running horse in all his surprising postures. In 1882, Dr. Marey, with a slit in a revolving disk (like Professor Pepper's) obtained pictures in one-eighth of a second. Chevreul placed three cameras over or against black backgrounds so as to photograph a flying bird from in front, at one side, and from above downward. Dr. Marey made his photographic gun, going 800 times faster than Janssen's "revolver."

What did Dr. Marey do next?

He loaded his chronophotographic gun with a ribbon sixty-six feet long. Its clock-work was moved by a dynamo. Upon the pulling of the trigger the entire ribbon would be filled with photographs. This gun was then applied to the movements of bacilli in the field of the microscope.

PHOTOGRAPHY IN THE THREE COLOR PROCESS.



THE PHOTOMICROGRAPH.
TAKING PICTURES THROUGH THE MICROSCOPE.

THE HUMANE HUNTER.

Give me some of the history of the Moving Pictures.

In 1887 photographs were made on a film ribbon in motion. The next year the paper ribbon of gelatino-bromide of silver was make transparent through the labors of Marey, Anchutz and Demeny. In 1893 Dr. Marey made his chronophotographic projector. It did not satisfy, because of a jerky motion. In 1894 Edison punched holes along the sides of the ribbon, and ran it over a cog-wheel spool that never stopped. He illuminated each picture the thousandth of a second. A single spectator could look into this kinetoscope. (See page 81.)

How did they transfer this to the Screen?

In 1895 a Frenchman named Lumière (that is, Light) adopted a triangular cam that kept the ribbon at rest two-thirds of the time. The tiny picture of a square inch on the ribbon was magnified to 20 feet square on the sheet.

Have cinematographic effects been recently improved?

Yes. Dr. Doyen, a French surgeon, has secured a stereoscopic effect for moving-pictures through the use of a kind of "opera-glass," which the beholder puts to his eyes. In this way the figures on the canvas stand and move about in relief, as seen in nature by the human eyes.

What is hydro-dynamic Photography?

Water is made to hold nicely-balanced spheres that will "take," and the movements of these spheres, in flumes, in waves, in water-falls, foam, whirlpools, etc., are followed by rapid photography, the supposition being that particles of water are pushing the spheres on their way.

Has this idea been applied to the Air?

Yes. Dr. Marey, Hele-Shaw and L. Mack have experimented with turbine wheels that inhale air. Many substances are placed in the air—silk, paper, smoke, etc.—and the motions of these substances are photographed. By Schlieren's method areas of differently-heated air become visible by refraction. The magnesium flash light is used. In this way ventilation and flying are studied.

What other things are photographed for moving pictures?

"Sounds" in air. Vibrations of chords in air. The locomotion of the eel and the ray in water. The motion of the dragon-fly in the air. The manometric flames—flames made like saw-teeth by sound—are rendered photogenic—that is, takable—by burning acetylene. Slow clouds may be made through their pictures to go so fast that the rhythm of their motions may be seen.

Are problems solved by means of these rapid pictures?

Yes. Difficult questions in geometry, mechanics, physics and physiology are frequently made easy. Solids may be created from the most puzzling elements. By dressing a man in black and marking certain joints or members, the actual movements of those portions of the body may be ascertained.

What other feat has been performed?

Prof. C. V. Boys, of England, has photographed bullets on passage from firearms, when these missiles were traveling at a speed of nearly 14 miles a second. The wake of air behind an elongated steel projectile was clearly visible in the photograph. These pictures, like those of sound-waves, were obtained by means of the electric spark.

When did the Astronomers take hold of the Camera?

The moon was first photographed by Prof. J. W. Draper, in 1840. The first daguerreotype of the sun was taken by Foucault and Fizeau in 1845. Vega was the first star photographed, in 1850, at Harvard. De la Rue photographed the first solar eclipse, in 1860. Dr. Huggins, in 1879, photographed the first spectrum of a star, and the nebula of Orion was the first of the nebulæ to be photographed.

How can the planets be photographed?

A stereoscopic picture of Saturn this side of the stars is obtained by taking the photographs a night apart. This separates the two eyes of the observer by about 1,600,000 miles. (See page 331.)

How are Asteroids found?

By setting a Camera in view of the heavens, and moving it with their apparent motion. An asteroid then makes a streak on the plate, and is thus discovered to be a traveling body among fixed points of light.

What wonderful work was done at Chicago?

About 1882, Janssen, then in India, and J. Norman Lockyer, then in England, simultaneously theorized that a number of prisms set in a semi-circle would carry around, say, the red ray of light from the sun, letting the other rays escape. The prominences on the sun were red, and in eclipses made a bright red hydrogen line in the spectrum. By viewing the limb or edge of the sun through such a set of prisms, and widening the slit of the spectroscope so as to make a thick red line across the spectrum (or ribbon of color if all the colors were there), the human eye, disembarrassed of the brilliant sunlight and lit only by hydrogen on the sun, beheld the prominences or spouting gas wells of the sun. George E. Hale, son of the man who invented the water elevator, built his own observatory, bought his own telescope, made a great compound spectroscope as described, attached it to the telescope (see illustration of reflecting telescope), and then, prefixing the camera to the entire apparatus, with his "telespectro-heliograph" took the first photographs of the entire periphery of the sun ever made by man. Professor Hale, thus justly celebrated as one of the leading astronomers of the world, was placed in charge of the Yerkes Observatory at Williams Bay, Wis.

Describe the present attempt to photograph the stars.

At an international congress of astronomers held at Paris in 1887, the heavens were apportioned among eighteen observatories in all parts of the world, from Helsingfors in the north to Melbourne in the south. It was agreed that each of these observatories should make photographs with instruments of a standard size and power. The chart thus to be made was to include stars of the fourteenth magnitude, and to contain about 20,000,000. Two millions of these stars are also to be cata-

logued. A star of the fourteenth magnitude is theorized to be 10,000 times fainter than a star of the fourth magnitude. The brightest star in the Little Dipper (Pleiades) is of the third magnitude; of the Big Dipper, second magnitude. The first magnitude stars in the "northern" skies are Vega, Arcturus, Capella, Betelguese, Rigel, Spica, Antares, Altair, Aldebaran, Regulus, Sirius, Procyon, Fomalhaut, and Pollux. Deneb and Castor probably have been brighter within historic times. Photographs of the spectra of these stars not only record their motions toward or away from our sun, but reveal the presence or prove the absence of companion-stars. It is a legend of the race that Sirius has crossed the Milky Way since the early ages.

Why can the photographic plate catch stars that the eye cannot see?

Because the plate can endure the long exposure required in which a fourteenth magnitude star beats down enough matter on a plate to make a record. While it can look, the human eye—imperfect as it may be, compared with other eyes—is superior to the plate. The camera is an eye; its lens, its dark chamber, its shutter, its plate, reproduce the apparatus of the eye.

What about radio-activity, as at p. 223?

All the new radio-active bodies there described act on sensitive plates through other bodies as solid as aluminium and vulcanite.

What other remarkable discoveries have been made of late?

Photographs have been taken with no other source of light or energy than the living human body in a dark room. Photographs have been taken by Electricity instead of Light (unless both are one).

How far has the color process gone?

A photographer in Russia can take a snap-shot in an ordinary camera, fitted with a peculiar screen. Let us suppose he thus photographs a brilliantly-colored cathedral. He may send the negative to Chicago, and there the printer can reproduce the picture in approximately the original colors of the cathedral, although he may have never seen the original coloring scheme. The workers in this line have been C. L. A. Brasseur, Sebastian

P. Sampolo, Gayton A. Douglas, and others. Dr. Lippman, of Paris, has been the most celebrated of the discoverers in this path of science. (See Chassagne at p. 331.)

Is this the "three-color process" as commonly known?

No. A much more highly complicated glass screen is used in the process above described. The ruling is 531 to the inch, and there are three "takings" on the same negative by means of shutters eclipsing portions of the screen, part of the time. At one of these takings a red or a blue or a yellow glass is interposed between the ruled screen and the negative. Three engravings are made from the negative, and these are printed on top of each other with three different inks, the light and shade of the engraving making the selection of colors.

Has counterfeiting been feared?

At one time (in 1902) the Government at Washington was seriously disturbed by the various reports attending the success of color-photography, fearing its application to the printing of United States currency, but it does not appear that such danger has arisen.

What new and humane sport has developed?

The sport of actually photographing wild birds and animals instead of killing them, A. Radcliffe Dugmore being a champion. Great risks are taken, particularly in climbing. A mouse with four young at suck in a native environment has been successfully photographed. Our illustration offers a view of highly creditable work done by Robert W. Hegner.

Give me an example of the practical problems offered in Photography.

A photo-engraver thus writes to Prof. S. H. Horgan: "I am a half-tone operator, and am having trouble with my bath. After sunning it works all right, but if I strengthen it with silver crystals there are oyster-shell markings, and dust covers the plate. Sunning cures it. My formula for collodion is: Ammonium iodide, 30 grains; cadmium iodide, 50 grains; strontium chloride, 10 grains; calcium chloride, 10 grains. I keep my

bath at 50." Prof. Horgan answered: "Shellac your hard rubber dipper, so the silver solution cannot get to it and combine with its sulphur, making the dust. Wipe the back and edges of the sensitized plate dry to prevent oyster-shell markings. Bath will be better at 40 grains of silver to the ounce. Change your collodion formula to 50 grains of ammonium and 30 of cadmium, and it will work better. To purify your bath: Add carbonate of soda; pour into a vessel containing a little water; bath turns a cream color; sun it a day; a black precipitate is thrown down; filter this out; boil the bath to a pasty mass; add water to make up original quantity; sun it till it is clear; filter; strengthen it till it registers 40; see that it is slightly acid—and it will work." This passage tells us volumes regarding the care and patience required to put our every-day pictures before us.

What is Coronium?

An element burning in the Corona, making a line at 1474 on Kirchhoff's scale, and first recognized by Prof. C. A. Young, Aug. 7, 1869. Many years later it was seen above Mount Vesuvius. The spectrum of the Corona with 30 lines was first photographed in 1882. The coronal streamers were first caught on the photographic plates in 1898.

What is the Sun's Reversing Layer?

As Sodium burns on the Sun it gives dark lines; when Sodium burns on Earth, the lines are bright. But in 1870, in Spain, at the total eclipse, just before totality, Prof. Young saw his entire spectrum of dark lines flash out bright, as if only earthly fires were burning. This gave knowledge of a layer on the outer edge of the Sun incapable of forcing its rays to us when the greater fires shone behind it. The Reversing Layer was first photographed in Nova Zembla in 1898 by Shackleton. It was again photographed in Sumatra in 1901.

What did Merritt Gally do?

This illustrious inventor applied his pneumatic motor and perforated paper "music" to the direction of nearly all the

instruments, including the cameras, of an eclipse expedition. An operator worked the pedals of a machine like a cottage organ; a ribbon of perforated paper only nine inches wide passed over a "chronographic barrel," and forty-eight instruments operated during the 125 seconds of total eclipse. Later an electrical commutator displaced the pneumatic apparatus, and was operated in Sumatra.

How is the Polariscope used?

The Polariscope—a set of prisms of Iceland spar, etc., that throws a double object on the screen—the Polarimeter, a Polariscope arranged telescopically and attached to a camera—these instruments were used in the eclipse of 1878 in Western America, in order to determine to what degree the Corona shone by itself or by reflected light. At the poles of the Sun the coronal light is caused mostly by reflection. The Polarimeter detects the degree of this polarization. There are usually several Polariscopes in an expedition's outfit.

What effect has Photography had upon the human mind?

In portraiture, particularly, Photography has conveyed ideas that could not previously be transmitted. By this means, more and more each year, the people form conclusions in regard to public men. The accepted portraits of Napoleon Bonaparte give only an approximate idea of his real looks, for he compelled his painters, David, Isabey, Raffet, etc., to depict him in the style of the Caesars, and that false concept became conventional. This result to-day would be impossible. Although the professional photographer does in a measure idealize both the looks and the size of his subjects, yet the traveling and amateur photographers are constantly taking views of men that are so startlingly true to life as to prove to the human eye its own lack of quick perception. One can see how absolutely impossible it would be to establish a conventional portrait of any of our latter-day Presidents of the United States, because the people have seen snap-shot pictures of them in many different postures. Still, there is a broad field for development even in this form of public education. Few people to-day realize how

comparatively tall Abraham Lincoln was in any group of men, or the exact stature of the King of England. Until Verestchagin, there had never been a painter who on canvas conveyed a real idea of war, but now the photographs of field, camp and hospital reveal, in all its details, the hideous character of human combat. In this way the popular imagination is curbed and ideality suffers, but ideality is only useful insofar as it is a very close running mate with the real. The old master-painters caused an awakening in the Church, because they alone could tell the tale of Mary and the Child to people basely ignorant. In a similar way to-day, the common people receive information (through the aid of photography) that was denied to all save the learned a half-century ago. In a city like Chicago, where so many tens of thousands of people cannot read the English language, the daily newspapers deal more and more with photogravures that speak a universal tongue, and the Russian, Czech or Syrian thus knows of flood, or fire, or riot, or parade, with nearly as much detail as the native English-speaking reader. The effect on general intelligence—on the public accuracy of thought—cannot but advance the culture of our race with great rapidity. The historical records thus accumulating are certain to be gratefully noted by future generations.

TAKING TRIAL SCENE FOR MOVING PICTURE THEATRE.

Light and Heat.

What do we know about Light?

Our theories grow more and more faulty as the experimenters advance in the actual treatment of Light. The Spectroscope is able to divide a small line of light into 140,000 cross-bars of light and darkness in each inch of the sun's spectrum, and this division may evidently go on to infinity; and, beside that, darkness may mean only darkness by comparison with greater light. Again, there are several kinds of rays that are not seen at all—making heat at the red end, making chemical change at the blue end of the spectrum. Then, still again, the X Rays exist. Red, green and blue are seemingly degrees of speed in the action of Light. (See Spectroscope.)

Is all this new?

All this is old, except the X Rays. You will find the following sentence from "Chambers' Encyclopedia" (article, Spectrum), printed in 1872, of especial interest since Dr. Roentgen's discovery: "What we can see is not the whole spectrum, but a mere fraction of it, for, beyond the red end, there are invisible rays, recognized at once by their heating powers; and beyond the violet there are invisible rays, more powerful than the visible in producing chemical changes, as on a photographic plate; these can be changed into visible rays by fluorescent substances."

What is Light?

An exhibition of Force acting on Matter. We have a fair idea of Matter, and a fair idea of Force. There still remains in

nature a thing, called Life (see Life), that is a closer union of Force and Matter than Light.

What was the invention of Chassagne?

He produced photographs in the colors of nature. He immersed a gelatine plate in a colorless solution of unrevealed character. On the gelatine plate a photographic negative was taken in the ordinary manner, and treated as any other negative would be treated. From this negative a photograph was printed on sensitized paper that had been treated with the colorless secret solution. So far there is no color-work. But the print has acquired the power to select the proper colors from color-solutions or dyes into which it is now dipped. There are three of these dippings, in three dyes—red, yellow and blue. Colors as difficult of production as mother-of-pearl and irridescent glass are thus secured on the paper print by the mere selective agency of the print.

What was done by the printers?

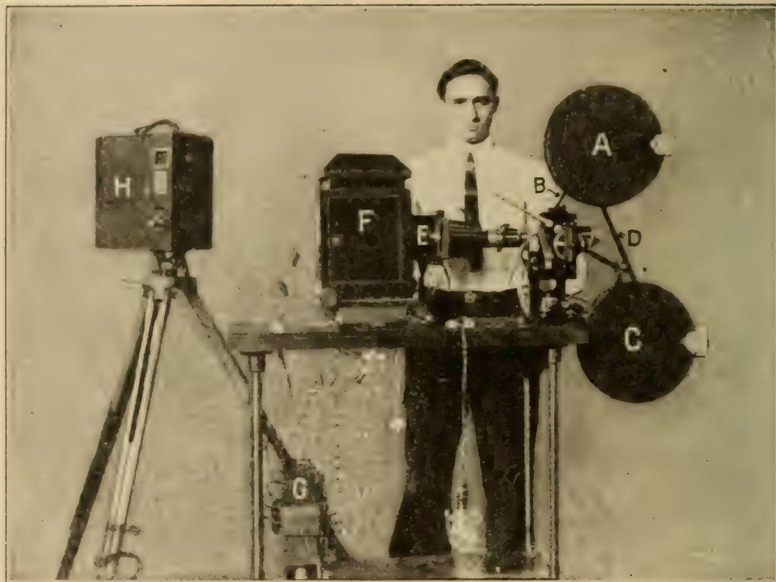
Wonderful imitations on paper of porcelain, rugs, carpets, oil-cloths and other colored articles of merchandise were secured by somewhat similar means—the printer putting his paper to press on half-tone photographic cuts or pictures in three colors of ink—red, white and yellow. Even a black was well simulated. The selective action of the colors was astonishing, and suggested the need of entirely new theories of the laws of Light and the ideas of color.

What is a Stereoscope?

It is an instrument which takes advantage of the fact that the two eyes of a human being form different images of objects within certain distances. Euclid made the first optical demonstration of this kind. Wheatstone and Brewster brought the Stereoscope to the form usually seen in parlors, where each eye looks through a refracting prism, and pictured weeds or trees in a field stand out in a photograph, as if the photograph were a real field.

What did this lead to?

The Magic Lantern was developed into a Stereopticon, and stereopticon pictures, much enlarged, were thrown upon a screen.



APPARATUS OF THE MOVING PICTURE MAN.

NO DRAMATIC or educational manifestation of modern times has equaled the importance of the Moving Picture. Under the influence of a popularity that has never diminished, beautiful theatres, often furnished with noble organs, have sprung up in almost every neighborhood, and again the drama and its adjuncts have become, as in early ages with the Greeks, the principal diversion of the masses. In the picture before us, we have the two sets of apparatus by which the scene is made possible before the audience On the left (at *H*) is the portable camera, with which the photographer records the moving scene before him, whatever it may be—a battle, a conflagration, a dramatic representation, or a scientific demonstration. The history of this great art of photography has occupied the preceding chapter. At the table by which the operator stands in the picture, is the apparatus necessary to the projection of the scene in the theatre. *A* is the film-holder, within which is the reel or film that is to be run off. *B* is the film, descending, to pass before the powerful light. *C* is the empty draw to receive the film after exposure. *D* (on a movable rod in front of the exposed film) is the lens that magnifies the little pictures into the size shown to the audience. *E* is the light-condenser. *F* is the light-chamber or lantern. *G* is the rheostat, or current-governor.

The extraordinary attraction which the Moving Pictures have for children, and the presence of so many youthful minds at the theatres, have given rise to the necessity of legal regulation and censorship. The powers wielded by the picture-censors, and the extent to which those powers should be exercised, have been the subjects of bitter discussion. The play-censorship of Europe (once so odious to all in America, and still no less odious to many) has become an established fact—an inevitable adjunct of one of the most important inventions of civilized man.

With the invention of the Kinetoscope, its passing pictures were placed in a Stereopticon (See Kinetoscope) and the wonderful reproductions of the Queen's Jubilee, the Czar's Coronation, the Corbett-Fitzsimmons encounter, the German military maneuvers, and other stirring scenes, were exhibited to the people under the names of Vitascope, Cinematographe, Ediscope, etc. The Edison Kinetoscope is a box holding the pictures, into which the spectator peers, beholding only miniature scenes, that move with extreme and unnatural rapidity.

What is Heat?

Heat is that thing which follows or causes certain activities of the molecules into which the Elements and their compounds are divided. If you take the temperature of your hand for a thermometer, then anything in which the molecules are revolving or meeting more rapidly than the molecules in your hand are revolving—that thing is warm or hot; if less rapidly, that thing is cool or cold.

How is Heat conducted?

Either by radiation through the air and through bodies in straight lines, or by means of conduction, in any direction from warmer to colder mediums. A radiant heat is a greater exhibition of energy. It may pass through a medium without heating the medium. The degree of energy is measured by the length of the wave sent across matter. If a radiant body send out waves that are each longer than eight hundred and twelve millionths of a millimeter—

But tell me what a millimeter is?

A centimeter is over three-eighths of an inch. A millimeter is one-tenth of this three-eighths of an inch. Divide this one-tenth into millionths, and if the wave is longer than 812 of these millionths, the eye cannot see the light, although the thermometer will make a record. At 812 the light is red; at 500, bright green; at 400, a feeble violet and the thermometer ceases to act, but the photographic plate has long shown increasing agitation; at 200 the eye sees no light again, but the photographic plate shows chemical change due to the battering of molecules.

Is Heat the same as Motion?

Under this theory, yes. All molecules are moving all the time. In solid bodies, as in gold, the path of the molecule is narrow. In fluids, the molecule moves through the entire extent of the fluid, meeting, clashing, rebounding, etc. In gases, the molecules move with highest velocities. Thus all gases must contain the greatest amount of Heat, liquids next and solids last.

What was Pepper's Ghost?

Prof. Pepper, an English lecturer, visited America late in the 70's and exhibited many remarkable optical phenomena, one of which is referred to at the close of our chapter on Electricity. In another experiment, which is illustrated at the head of this chapter, Prof. Pepper was able to project the reflection of a young woman as a ghost upon the stage. She walked about the stage, walked through the Professor, and he accompanied the scene with a somewhat dramatic monologue. Pepper's Ghost created a popular sensation, and the lectures were largely attended in America.

Why should we deal with Light and Heat in this chapter?

Because of our daily needs, at home and abroad. Our source of Light and Heat, the sun, is shut away from us for many hours each day. We therefore set forces at work, or liberate forces that agitate molecules of matter until our needs are supplied.

What is our best artificial Light?

So far, Electricity furnishes it, and we have described, in the chapter on Electricity, the manner in which the two common forms of Electric Light are furnished to the people.

What is the commonest Light?

That produced by burning a wick whose lower end is immersed in Kerosene. Lamps for this purpose have been produced of every size and form, and stoves, both for heating and cooking, have long been in use. Great difficulty has arisen in overcoming the tendency of the lamp or stove to give off an odor.

Where does Kerosene come from?

It is refined from Petroleum, or rock oil, which flows or is pumped from wells sunk in various parts of the earth's surface, in fact, at last, all round the world. The word Kerosene is also *wax-ene*, for *Keros* in Greek, means *wax*.

What is Petroleum?

It is one stage in a series of untheorized chemical changes in hydro-carbon molecules. Naphtha may be found flowing out of the earth, a clear, limpid fluid. On reaching and mixing with

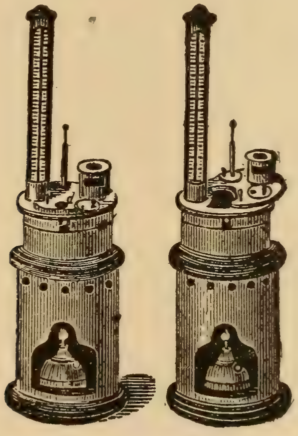


Fig. 123. TAGLIABUE'S APPARATUS FOR TESTING COAL OIL.

air, it grows thicker, and is Petroleum. Further exposure and contamination turn it into mineral tar. As it hardens it becomes asphalt or bitumen. There is no bitumen in what the miners call bituminous coal.

Where was Petroleum discovered in America?

On Oil Creek, a tributary of Allegheny River, in Western Pennsylvania. Col. G. L. Drake drilled a well in 1859. The great oil excitement and speculation did not come until war-time, and the first person enriched—called "Coal Oil Johnny," made a sensation with his easily-gotten money. Cities rose and fell, and there are places now devoid of inhabitants,

where once were hotels, telegraph offices, daily papers and "opera-houses." In those days, the wells spouted crude oil,

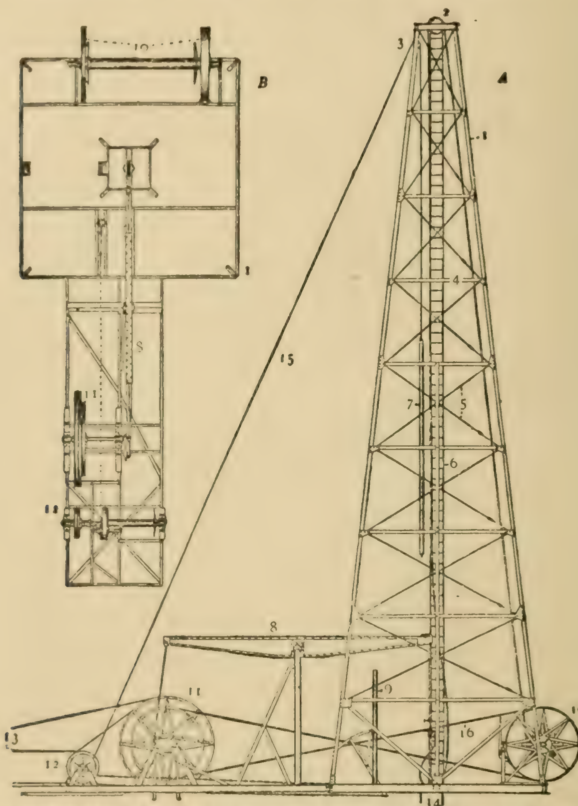


Fig. 123½. DIAGRAM OF A STELL RIG FOR DRILLING OIL WELLS.

A, Upright plan. B, Ground plan. 1, Derrick Frame. 2, Crown pulley. 3, Sand pump pulley. 4, Derrick girt. 5, Braces. 6. Ladder. 7, Bailer. 8, Walking Beam. 9, Headache post. 10, Bull wheels. 11, Band wheels. 12, Sand reel. 13, Ropes connecting with steam engine. 14, Top of well. 15, Sand line. 16, Bull rope.

and it ran to waste. But no gas wells had been found. The oil region gradually extended westward into Ohio.

What finally followed the discovery of Oil Wells?

The largest monopoly of trade in oil or, any other substance, that the world has seen. In 1870, the oil firm of Rockefeller,

Andrews & Flagler, at Cleveland, formed the Standard Oil Company. This parent organization finally headed the Standard Oil Trust. In 1895, the ownership of the American fields and the Russian fields on the Caspian Sea at the Caucasus Mountains, were consolidated. A great refinery was established at Whiting, Indiana, near Chicago, and hundreds of vast tanks, like gas-holders, may be seen there as railway passengers from the East go to the western cities. The Standard Oil interests are perhaps the largest property ever held in ownership by private citizens in the history of the world.

How does the Crude Oil get to Whiting?

Principally by a pipe that runs through Indiana. The pipe empties into the great oil-holders, where it is "tanked"—that is, the water separates from it—about two per cent.

How is Petroleum refined?

It goes to a boiler with a still attachment. About twelve thousand gallons are thus treated at a time. Live steam is injected, and a vapor of gasoline and naphtha rises into a worm and is condensed into liquids, to be further refined, the naphtha becoming benzine. About eighty-five per cent, of oil is left. This goes to another still, where it is mixed with a solution of a sodium compound and heated. Over half of the oil goes through the worm, and is condensed as crude illuminating oil.

How is the Crude Oil refined?

Four ounces of sulphuric acid to the gallon of oil are added, and the mass is agitated for half an hour. A tarry residue has then precipitated with the acid. The oil is passed through water, to wash it clean of sulphur; two per cent. of a sodium compound is again put in, agitated, and the oil again passed through water. The oil is then pumped into a fire still and distilled in a last solution of sodium compound. The oil that comes from the worm is now snow white, and is barreled in glue barrels or shipped in five gallon cans. The by-products are themselves refined, if necessary.

Name these by-products of Petroleum.

About fifty-four per cent. of illuminating oil for your lamp

was secured ; there will be seventeen per cent. of fine machinery oils ; fifteen per cent. of naphtha (three grades) ; two per cent. of gasoline ; two per cent. of paraffine wax; and a loss of about ten per cent.

What great feat was accomplished with Crude Oil?

The largest battery of steam boilers ever set up in the world was heated by burning sprayed crude oil at the Chicago Fair of 1893. Steam for 27,000 horse-power of machinery was furnished without smoke or soot from the chimneys, leaving the buildings of the World's Fair white and clean, and its atmosphere pure.

What artificial Light did the Kerosene Lamp immediately displace?

The old "Spirit Lamp," in which amphene was burned. The wick came up through two tubes, which had hoods, that must be put on the tubes when the Lamp was out of use.

What was used before the Spirit Lamp?

The Candle, variously made, which was an improvement of the ancient Oil Lamp, in which a loose wick hung over the edge, or spout or "beak," of an open vessel. Candles were made of tallow, in tin or zinc molds, in nearly every rural American household as late as 1860.

What had the Cities done, in the meantime, to light themselves?

They had set up gas-works, piped their streets and houses, and furnished an artificial Light that still holds its ground on account of economy, safety and convenience. In some ways, such as out-door illumination, the Electric Arc-Light has succeeded, at the expense of the gas companies.

Was Gas known to the Ancients?

Yes. The gas-wells at Baku, on the Caspian Sea, were burning when Thothmes III. pushed the power of Egypt to that quarter, early in the history of civilization. The Chinese have had gas-wells, with pipes of bamboo, for ages.

How did Gas-Making begin in England?

There had been a burning well at Wigan, which set the

philosophers to the making of theories. Finally, they distilled gas from coal, and Clayton, late in the seventeenth century (about 1688), read his paper before the Royal Society. He had filled a bladder with gas. In his paper he said: "I kept this spirit in bladders a considerable time, and endeavored several ways to condense it, but in vain; and when I had a mind to divert strangers or friends, I have frequently taken one of these bladders and pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming until all the spirit was compressed out of the bladder, which was the more surprising because no one could discern any difference in appearance between these bladders and those filled with common air."

What may we deduce from this extract?

That the English race was slow in paying attention to the results of the chemical researches of the Arabian and Latin races, for here we have a definite record that the "inflammable air" (about 1688) was a novelty to all the English scientists. Probably there was no book in England that dealt with the learning of the alchemists.

But did not the English make the first practical use of this knowledge of Gas?

Yes. Murdoch erected Gas-works in Cornwall, in 1792. Biringham and other cities were lighted early in the nineteenth century. Moscow did not obtain commercial Gas until 1866.

Describe the modern Gas-Works.

The most notable construction is the Gas-holder. This is the reservoir for the supply. It is a vast tank upside down. Its sides are in water, and as the Gas enters, the tank's top rises up, sometimes with telescopic sections, enlarging as it rises. At dark the tank towers high, and sinks as the Gas escapes all night into the service pipes. There may be several Gas-holders, according to the consumption in the area covered by the Company. But the holders are made very large, and often there is but one.

What is the Gas Retort?

It is one of the ovens set over the fire. A furnace has four

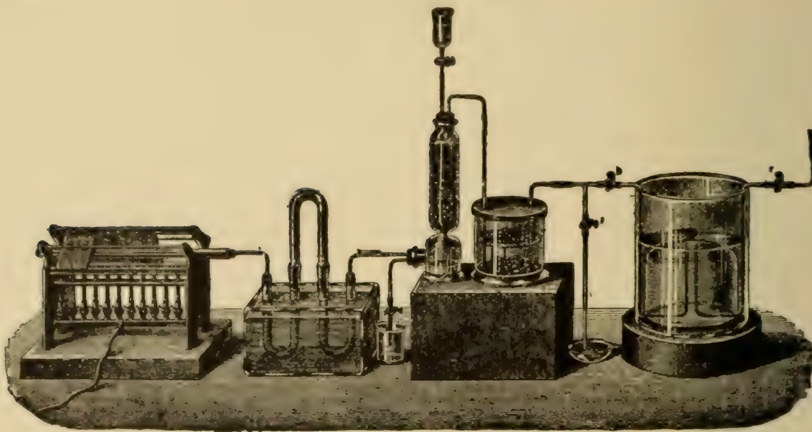


Fig. 124. APPARATUS FOR ILLUSTRATING THE MANUFACTURE OF ILLUMINATING GAS.

brick tubes or ovens, usually flat on the bottom and circular overhead. In these tubes, nine feet long, the coal is baked or roasted until it gives off all its vapor.

What is Coke?

It is the coal after it has been thus baked.

Where does the Vapor or Gas go?

It rises in an ascension pipe leading out of each retort. The ascension pipes unite above and pass in a tortuous way over a hydraulic main or trench of water, into which tar and other heavy matters drop. This main runs to the tar-well. As the Gas passes away from the fire and presses forward to get out, the pushing from behind is cut away as much as possible, in order to obtain a better quality with more time for chemical action.

What is the Scrubber?

This is a purifier for the purpose of removing ammonia compounds. The object is to give the ammonia the widest opportunity to meet water, with which it has a remarkable affinity, and to give the hydrogen and carbon, where united, as little water as possible. A strong ammonia water is desired as a by-

product. The scrubber is a double coke filter. The Gas goes up one side and comes down the other, while sprays of weak ammonia water trickle down, attracting the ammonia molecules in the Gas that goes by.

What is the Purifier?

It may be a set of trays on which lime, or chemicals (the oxide of iron) are exposed. The Gas passes over these trays, and the lime attracts the impurities—carbonic acid and sulphur. The

Fig. 70.

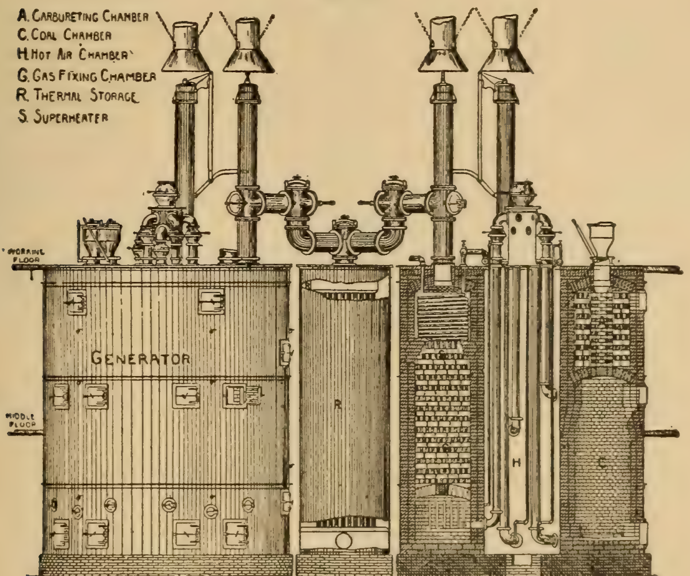


Fig. 125. THE ROSE-HASTINGS COAL-GAS APPARATUS.

cleansing apparatus often adds components to the Gas.

What is the course, from Coal to Gas?

Soft Coal goes into the ovens or retorts. The Gas rises into the condensers and the tar runs out. From this tar, with other chemicals, the aniline dyes are made. The Gas goes to the scrubber, to the exhauster (which stops the pressure), to the purifier, to the meter, to the Gas-holder.

How does the House-Meter work?

If it is a dry meter, which is probable, the pipe from the street enters the first or bottom of two leather bellows or measures. This bellows rises until it opens a valve in the upper bellows, when it collapses, and the upper bellows fills. Then the process begins once more. The bellows as it collapses, moves a steel arm. This arm is on a vertical shaft that starts a train of wheels. Every five bellowsfuls make two cubic feet of gas, and the wheel represented by the top hand on the outside dial of the meter makes one revolution. The top hand is called the test hand, and it should stand still all day, or your meter records the escape of Gas.

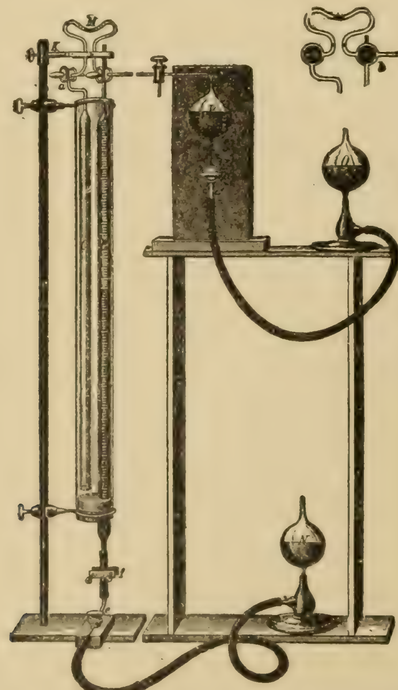


Fig. 126. APPARATUS FOR GAS ANALYSIS.

How nearly accurate is this Meter?

It may run fifteen per cent. fast or slow. The cities have

inspection-departments, and it a householder believes his meter is fast, he may deposit a fee—say $2.50—and his meter must then be taken to the city hall by the Gas Company. If it be fast, his fee is returned to him, a rebate is collected from the Gas Company, covering several months past, and a correct meter is put in his house. But, if his meter prove to be slow, his fee is not returned, nor is his slow meter. Meters are tested with air, at the pressure of Gas. We illustrate the apparatus for the inspection and testing of the Gas itself.

Describe the Pintsch Light.

By means of this device railway and street cars are illuminated. The system was invented by Julius Pintsch, of Berlin, who made a Gas from Petroleum that could be compressed like air, without condensation into a permanent liquid. City Gas, from coal, cannot be thus stored. Gas works for making Pintsch Gas are established in all the large cities of the world. The process is not unlike that already described, the only great difference lying in the use of oil instead of coal. After the vapor rises from the retort, it is cleansed of tar, sulphur, and the heavy hydro-carbons in the same way, the last purifier being oxide of iron. It is put into the Gas-mains under a pressure of fifteen atmospheres, and these mains lead to the depots whence the passenger trains take their departure. Under each passenger car that has Pintsch Gas Light is a long cylinder, like the air-brake chambers. This is charged from the Compressed-Gas pipe. On the way from the cylinder to the car-lamp, the Gas is expanded until the pressure is only a few ounces to the square inch. Thus we ride in a railway car that is lighted by Gas, and the Gas never or rarely gives out during the journey, however long. About seventy railway companies use the Pintsch system. It has also been applied to cable street cars.

What great thing followed the finding of Gas Wells?

About 1884, the city of Pittsburg, the largest producer of iron, steel and glass in the United States, succeeded in using gas from the wells for all of the manufacturing purposes save the iron smelting, and the pall of smoke that had covered the city passed away. The Gas-field extended rapidly westward into

Ohio and Indiana. The greatest excitement and speculation attended the discovery of the supplies of Gas under Findlay, O. Pipes were laid to Toledo and further on to Detroit, where many thousand residences were served with Fuel Gas the first year. Indianapolis, Ind., was thus heated for several years before the pipes reached Chicago. At Chicago, the pipes were carried only into the south side of the city. The effect on the price of coal was to cheapen it, but the Gas-wells failed to keep up their pressure, and at the same time the price of coal advanced. But the fact that so many persons in five States were long served with fuel from the interior of the earth, must remain one of the most striking episodes of history.

What is Coal?

It is a fossil fuel—largely carbon—the result of baking or roasting forests, or forest-growth under coverings of clay and water with great heat, such as the internal fires of the earth. The wood, grass, leaves and some earthy metals are compressed into a formless mass, usually black. It is said that there are in certain parts of the world evidences of the growth of thirty forests on top of one another, forming that many strata or layers of Coal.

There are two kinds of Coal?

Yes, hard and soft. The hard Coal is called Anthracite, from the Greek name for Coal. The soft is called Bituminous, but there is no Bitumen (Asphalt) in it.

When we burn Coal, what Elements remain unburned in the ashes?

Mainly sand, clay, iron and lime, being silicon, aluminium, iron oxide and calcium. There are small quantities of magnesium, potassium, sulphur and phosphorus, with hydrogen.

What become of the Ashes of a great city?

They are solid, incompressible, and gradually lift the site. They are the main item in the debris of cities. Ancient cities are found to have accumulated as much as eighty feet of earth in this manner. The centre of Chicago is now ten feet higher than the site on which Fort Dearborn was built. The pavement

of the time of the great fire, lies about eighteen inches below the present streets.

Where is the Anthracite Coal found?

There are three basins in Pennsylvania. Other parts of the world furnish it, and it is called "Stone Coal" in Great Britain. When Coal is broken for household use, the English call it "Coals." The French and other Latin races call it Carbon—the French say Charbon de terre, that is, Carbon of the earth. Hard Coal is practically quarried. Soft Coal is tunneled for, and dug out of the earth with much more discomfort.

Anthracite was not thought to be combustible at first?

No. As late as 1812, of nine wagons of Anthracite Coal hauled to Philadelphia, only two could be sold at cost of transportation. The rest was given away, with difficulty. The persons who bought the Coal could not set it on fire, and threatened prosecution on criminal charges. This was one hundred years after the making of bar iron in America. It is now regarded as the best solid fuel that has been discovered. The ownership of the Anthracite mines, together with the high esteem in which the fuel is held, has given rise to a fuel monopoly. The failure of the Gas-wells has strengthened the monopoly.

What is a Coal-Breaker?

It is a terraced building in the Anthracite region. It rises over the mouth of a Coal-mine, and its lowest terrace is a shed for the loading of railway cars. It takes its name from the machine by which Coal is broken into the various sizes of "egg," "range," "chestnut" and "pea."

Where is this Breaking Machine?

At the top of the building. The car of Coal rises from the shaft with a miner's metal check hanging to it. The weigh-boss credits the miner with the amount in the car. The car is dumped on a slanting screen with bars wide apart. Under the screen is an iron platform, which receives the screened Coal. This platform also slants, so that the Coal works out from under the screen. Here men with picks examine the big pieces of coal, to find slate, and knock it off. The platform gradually

slides the Coal into a hopper. Underneath are the rolls with steel teeth—the breakers. With disagreeable noise, the teeth crunch the Coal and send the broken pieces in a chute to the revolving screen or separator. This separator throws the various sizes into their own chutes. But there is slate in the Coal, and, while it goes down the chutes, boys in rows, under the sharp watch of a superintendent, pick the pieces of slate out of the Coal. They grow very expert in eye and touch. The refuse picked out is called culm, and this rises in mountains outside the breakers. The process of breaking, rebreaking, picking and washing, varies with necessity or inclination, but in a mine of good Coal is usually as simple as has been described.

What is the Mine Shaft?

A four-sectioned well, in which the ascending and descending cars occupy two parts, the ventilating shaft a third part, and an escape-shaft the fourth part. The cages go up and down 2,000 feet a minute.

What are the Gang-Ways?

These are the tunnels leading from the shaft to the places where the miners are at work. Rails are laid in the gang-ways, and the Coal-cars run on these rails. The gang-ways are well-timbered.

What are the Air-Ways?

These are separate tunnels running parallel with the gang-ways, by which air is sucked from the furthermost chamber of the mine. The gang-ways connect by cross-cuts with the air-ways.

Describe the ventilation of a Mine.

The Anthracite miner has the advantage of plenty of Coal, with "pockets" sometimes sixty feet deep. But gas and "damps" are his menace. To make the mine safe, a circulation of air must be maintained. At the top of the ventilating shaft, an exhaust-fan sucks air out of the ventilating tunnels. The fresh air goes down the car shaft and into the gang-ways. It follows that all cross-cuts must have doors. The boys who open

and close these doors are called "door-tenders" and "trappers." The trappers in Scotland used to work eighteen hours a day.

What is the "Breast" in the Coal-mine?

The "breast" or "face" of the Coal is the open part of the vein, against which the miner works. He drills holes in the Coal, as if it were rock, puts in dynamite cartridges, makes the blast, and then sets the "laborer" or helper filling the car. The driver carries out the Coal, a mule pulling the car.

Suppose the Coal-vein slants downward?

The gangway from the shaft then approaches this slanting vein. The miner makes a chute upward at the slant of the vein, exposing its face. He then works in this chute, and the Coal tumbles downward to the car in the gang-way. When the vein has been worked up to the old level, the main shaft of the mine is sunk still lower, and another gangway goes out still further under the descending vein.

What is the order of learning the trade of Coal-mining?

As a boy, the miner picks slate. Then he goes into the mine and tends door. Then he drives cars. Then he becomes a "laborer," helping the miner. At last, he drills the holes and fires the shot.

How does Soft Coal Mining differ?

The miners of say, Illinois, have only thin veins, and cannot use dynamite satisfactorily. There is more danger from cave-ins. There are no chambers, and the miner must often stoop over. Water is a constant menace. In soft Coal mines, there are no pillars left. In Pennsylvania it is said that 40 per cent. of the Coal is thus used for support.

How much Anthracite is in sight?

The experts vary in their estimates. From ten to twenty-five billion tons are said to remain. The output is forty million tons. The Anthracite Basin covers 475 square miles. No soft Coal is present. No Anthracite Coal is found in the regions of soft Coal, which extend nearly all over the rest of the United States. The Anthracite vein is not less than three feet thick. It may swell to sixty feet. It dips to 3,000 feet below the surface of the earth.

How is a Coal Field placed, geologically?

First, there may be a bed of clay, filled with fossils that were once the roots of large trees. Then comes the vein of Coal. On top of this lies the roof, a slatey clay, with leaves, stems, fruits, shells, pebbles and all the sediment that would gather at the bottom of water. Sometimes trees are imbedded in the lower clay, while their trunks run through the coal vein.

Describe the celebrated cliff on the Bay of Fundy, in Nova Scotia?

Here the water has laid bare the side of a cliff hundreds of feet high on the southern shore. The layers of the cliff are thus exposed, and they are composed of Coal, clay, grit and shale. Erect trees, in fossil state, are seen on the face of the cliff, and series of these stand, one above the other, actually showing the growth and destruction of one forest after another.

What has happened to Coal geologically?

Study of the carboniferous strata of the earth leads us to believe that a soil was made ; a forest of fern-trees and ever-greens grew ; water and mud destroyed it, or killed it ; heat or fermentation with pressure condensed the vegetation into Coal ; the surface of the earth was again heaved above water ; a forest grew ; and so on some thirty times. The climate was hot, everywhere. This is the history of the carboniferous era. How much of the heat and pressure was from the inner fires of the earth, how much was chemical foment and top weight, are variously theorized.

What Animal Life existed in the Carbon forests?

Not much, for the reason that the earth was still in groups of islands. There were many fishes, snails and small shell-fish. There were no birds. A sort of crocodile lived, and amphibious creatures like the lizards were numerous. Of the ferns and pines about three hundred and thirty species are found in the true Coal-veins of Great Britian. The very last stratum of earth, now making, only shows about two hundred and twenty species. Five lower formations, all above the Coal, are comparatively poor in vegetable growth.

What do the Irish peat-bogs show?

Submerged trees are found, which have been dyed black with iron compounds. The wood is sound and hard, and can be used as timber. The next stage toward Coal, is when the peat or the tree turns to *lignite*, or brown Coal, soft, easily split, burning to a large residue of white ash. Jet is a product of lignite, and is very light. Soft Coal is the next stage. Anthracite is the coal which, under pressure has been "cupelled" in the hottest fires, or heated the most chemically, with no opportunity of reaching the air.

What other Fuel do we possess?

The Wood that has not been turned to Coal, or Gas, or Oil. This was once the chief fuel of the Eastern States. Where the forests were to be cleared, the pioneers could not wait, and even burned the logs in great piles, with enormous waste. Wood makes a hot but smoky fire.

What is Charcoal?

Charred Wood. Great pyramids are built of cut Wood, and these pyramids are covered with earth. The pile is then set on fire, and burns with insufficient air, turning the heap to Charcoal. Charcoal is the great fuel in hot countries like Mexico. It is used in carbonizing iron into steel. It is a powerful disinfectant. It is used in making gunpowder. Wherever heat without smoke is required, as in tailors' irons, etc., Charcoal is used. It is always for sale at city wood-yards.

Does Electricity furnish Heat?

Yes. There are Electric Kitchens at the pure food fairs, and we have in the chapter on Electricity, noted the practical application of Electric heat to the warming of railway cars.

Ice.

What is Ice?

Water, from which half the heat has been taken. The molecules, in arranging themselves anew, lose a part of their weight, gain in size, and float on the water, with a portion of the Ice mass projecting from the water. As this portion is small, when one sees a gigantic iceberg in the water, he may calculate the mass that is submerged, as the floating Ice in our pitcher is the same sort of an iceberg, on a smaller scale.

How do we make use of Ice?

We inclose it in a box or chamber, and it rapidly absorbs heat from the air, reducing the temperature to a point at which decay in other things is arrested. In order to melt, Ice must absorb the exact amount of heat that the water lost when it froze. Agassiz has written the most interesting of essays on the physical process by which a block of Ice melts, and how the globule of water forces its way through the block of Ice.

How do we usually obtain our Ice?

Great houses are constructed at the borders of our small lakes, and blocks of Ice are cut and piled in layers of sawdust. The machinery for storing and unloading, yearly improves. This Ice is carried to the cities in train-loads, and this is the product that is loaded into the refrigerator cars that now form so large a part of our freight rolling stock.

Why did Ice-making begin as an industry?

Because in very warm climates the natural Ice melted in long

transit by rail. Again, even in cold climates, the Ice-harvesters leagued together and put prices to a point that justified a chemical product. Artificial Ice has the advantages of purity and solidity, the latter quality making it more efficient as an absorbant of heat.

How did the Artificial or Chemical Refrigeration begin?

The packing-houses of the north found that they could economize by building a cold room in which pipes filled with brine absorbed heat. Here the temperature was more equable, the air was dryer, and the labor of carrying Ice and washing it was omitted.

What was the principle of making Ice?

If Ice takes up heat, some other substance could be found that would take up heat faster. In this way water could be frozen by having this substance absorb heat from the water. Hundreds of such substances were at once suggested, but commercially, ammonia, a gas compressed to liquid, was accepted.

Describe an Ice Factory.

The plant includes heavy machinery—steam boiler, engines, pumps, condensers, pipes and tanks, but the process is simple. The freezing apparatus is a tank of salt-water, which itself does not freeze. Through this brine run pipes carrying ammonia, which is expanding rapidly into gas, and withdrawing heat from the brine as it goes through the pipes that are submerged in the brine.

So the Brine gets very cold?

Yes. At zero and below it does not freeze. But closed cans holding pure water, freeze when put in the brine.

How large is the Brine Tank?

About fifty feet long, twenty feet wide and four feet deep. It sets in the floor, and is covered when the cans are freezing. Cans, holding distilled water, are set in rows across the tank, and are not allowed to rest on the bottom of the tank. These cans usually measure forty-four by twenty-two by eleven inches in size. They are filled with great care, so as to exclude

bubbles of air. The tank is covered up. The ammonia-pipes run through the brine between each row of cans. The water in the can freezes solidly in less than three days.

How is the Can of Ice handled?

A traveling crane lifts the can, tilts it upside down, carries it to an inclined plane, and sets it under a stream of warm water. The Ice slides out of the warm can, and down the incline to the ice-house. A restaurant-keeper can have his lobster or fish hung in the can before it is frozen, and it comes out surrounded by pure Ice.

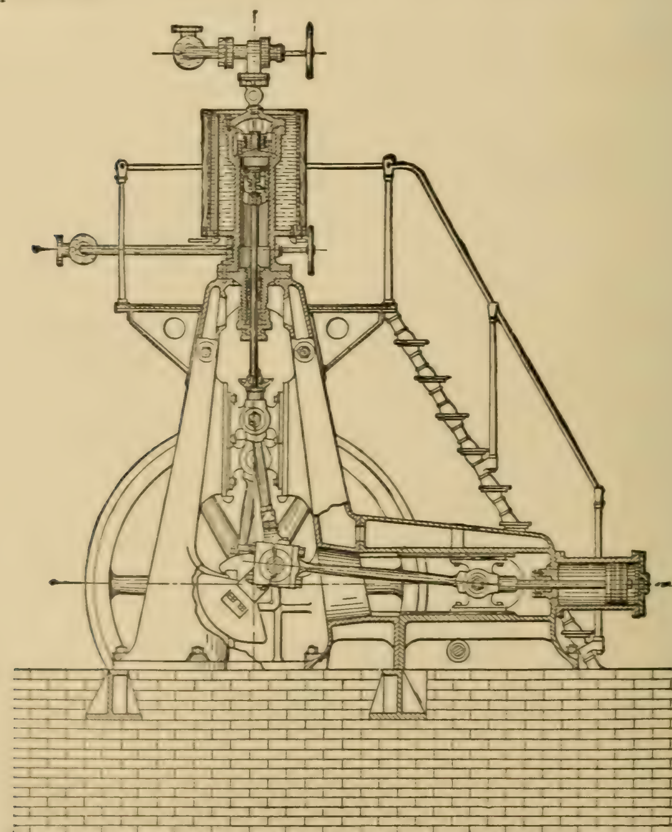


Fig. 127 ICE-MAKING MACHINE.

Now for the Ice Machinery?

This is the engine or pump which keeps the ammonia in circulation. One stroke of the piston sucks in a quantity of ammonia as a gas; the same stroke presses another cylinder-full into a liquid. This liquid has suddenly lost a vast amount of heat under pressure. Now turn the liquid into the pipes that go through the brine and it will expand into a gas again, but not until it has absorbed all the heat that it lost. This heat it can get nowhere but in the brine, and the brine must get what it can out of the water-cans, and the water in the cans freezes. The brine is usually kept at eighteen degrees below zero. When the ammonia has expanded into gas again, it is ready to go back in the circuit to the piston, which gives it another squeeze. Mechanical power may be aided by cold condensation of the gas.

What establishments must have freezing plants of this order?

All breweries, packing-houses, cold-storage warehouses for fruit, meat, etc. Great hotels and kitchens may be thus served. Pleasure-houses can be cooled. There are large store-rooms in the great cities where the hoar-frost seldom or never leaves the pipes that surround the room, and even covers the ceiling and walls with its crystals.

Do the tunnelers use this system?

Yes. The ammonia pump may be set at the mouth of the shaft, and brine pipes may be sent into the tunnel. Pipes may be driven into quicksand and the entire cylinder will freeze so that it may be cut out like rock. A difficult quicksand pit in the four-mile water tunnel at Chicago was thus mined.

Fig. 128. COTTON, FROM FIELD TO FACTORY.

Clothes, Etc.

Where do our Clothes, our Bedding, and our Carpets, Curtains and Hangings come from?

They are made from Linen, Woolen, Cotton and Silk. On each of these materials and the processes of using them, great libraries exist.

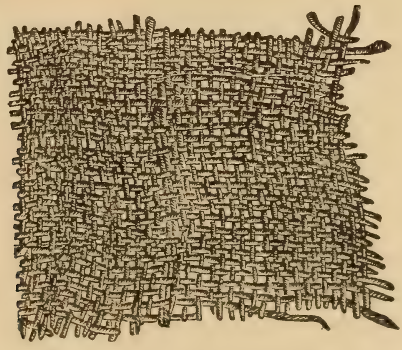


Fig. 129 PRE-HISTORIC FLAX CLOTH, FROM A LAKE DWELLING.

With what did Man first Clothe himself?

With the skins of beasts. From these skins it might be that Woolen garments evolved. But Linen (flax) Cloth is found as a relic of the stone age, and is therefore prehistoric. Cotton Cloth is found in the graveyards of Ancon, in Peru, which are pre-historic.

What is probably our oldest tradition on this subject?

Lenormant states that the Jerusalem Talmud attributes the

making of Cloth to Naamah, the daughter of Lamech, and sister of Tubal-Cain. Thus the Hebrews held to a tradition that the great, great, great, great, great grand-daughter of Adam first spun the Wool of the flocks and wove the thread into Cloth. All our industrial arts are attributed to the family of Cain, the murderer, to which Naamah (meaning *pleasant*) belonged.

What is Silk?

Silk is the gummy, fibrous exudation of a worm, and resembles hair and horn in its chemical structure—that is, it is made of the protoplasm Elements—hydrogen, oxygen, nitrogen, and carbon (See Life and Chemistry). The process of turning the exuda-

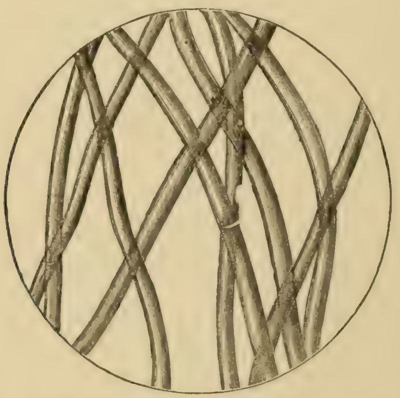


Fig. 130. SILK FIBRES ON THE MICROSCOPIC SLIDE.

tions of the silk-worm into Cloth was a secret of the Chinese for ages. In China, the word for Silk was *See*. The western nations called it *Seer*. Accordingly, they called China the Land of Silk, or *Seres*. The Greeks said *Sericon* for Silk, the Romans, *Sericum*, and the French *Soie*, (probably from *Soi*, the native name in Corea). For ages, the Europeans wore Silk without knowing what it was made of, the belief being general that the Cloth came directly from the mulberry tree. In the time of Henry VIII, of England, if a man's wife wore a Silk gown, he must furnish a war-horse for the King.

How does the Worm produce Silk?

By making a cocoon in which to lie until nature transforms the worm into a moth. Silk could be made from all cocoons of all insects of that order, and from the exudations of all insects that construct webs or spin "gossamer." The Silk-making insect of commerce is the *bombyx mori*, a mulberry-feeding moth. The worm, before it becomes a moth, and at its birth, begins eating mulberry leaves, and consumes double its weight daily. In five weeks it has grown three inches long, but only slightly larger in girth than a lead-pencil.

How does the Worm make the Cocoon?

It ejects the gum called Silk from two tubes near its mouth. The two lines join as soon as they touch each other and form the natural strand, sticking together because they are wet. The line adheres to the branch which it first touched, and the worm then either turns over and over, or with its very flexible mouth or proboscis, throws the line in a circle, forming the walls of the cocoon. Gradually a chamber is made, with the worm inside still turning over and over, and gradually squeezing its body into smaller compass. It seems to be nearly dead when its work is ended.

Fig. 132. SILK-SECRETING APPARATUS IN THE WORM.

Does the Moth hatch out?

No. At the end of about the eighth day, the worm is killed by the Silk-makers, because, in issuing from its habitation, the moth would injure the cocoon. The Silk-makers expose the cocoons to steady sunshine or other heat, and the worm dies.

Is the Cocoon all merchantable Silk?

Yes. A part of it will be reeled off into first-class goods. The remainder will be carded into spun Silk, an inferior grade. There are four thousand yards of

the double line. Of this length not more than seven hundred

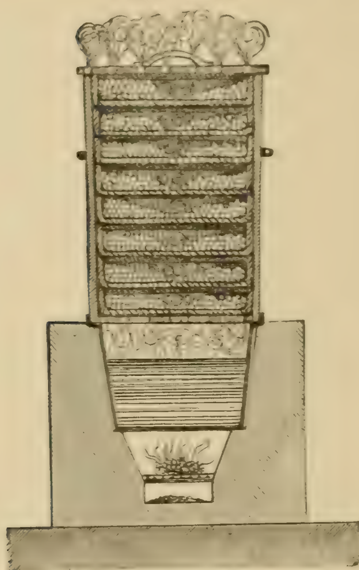


Fig. 133. APPARATUS FOR STIFLING THE SILK WORM.

yards are likely to come off on the reel. The rest is too fine or sticky to be handled by reeling.

How are the Cocoons reeled?

From six to ten of the cocoons are put in a basin of hot soft water. With a whisk broom or similar implement, they are submerged, and the end of the thread sticks to the broom. All the ends of the cocoons are collected, passed together through a guide-eye, and tied to the bar of a large reel that is placed far enough away to assure the drying of the filaments in passing through the air. The French call the reeling-establishments "filatures." The reel is slowly turned and the operator watches the water, to see that all the cocoons keep bobbing, as otherwise he would have no knowledge that a thread had broken in the strand. An expert can reel five ounces in ten hours. When a single thread breaks it is mended by sticking the ends together. If the entire strand break, a knot must be made. When enough

Silk has been reeled to make a skein, it is removed from the reel, dried, and packed in "books" of from five to ten pounds. These books are packed into bales of one hundred and thirty-three and one-third pounds. This is raw Silk. The rest of the cocoon is shipped as waste Silk.

How much of this Silk material comes to America?

It is not unusual for our Silk manufacturers to import three hundred thousand or four hundred thousand pounds of cocoons, eight million pounds of reeled Silk (at three or four dollars a pound), and a million pounds of waste.

What is done with the raw Silk?

It is now in skeins of thread in which there are from six to ten filaments. The skeins are soaked in warm soap-suds, and then hung on a reel which is called a swift. From the swift the Silk goes on a bobbin that moves as a boy winds his kite-string, so that the Silk travels the long way of the bobbin. This imparts some lustre to the thread. Next is the first spinning-frame, where the thread gets the first twist it has received. The worm made a double thread; the reeler made a thread from six to ten of these double threads. Now it is finished, because otherwise, in the cleaning all these filaments might come apart and make floss. The spindle that twists the thread revolves at a speed of ten thousand revolutions a minute.

What is all this Silk process called?

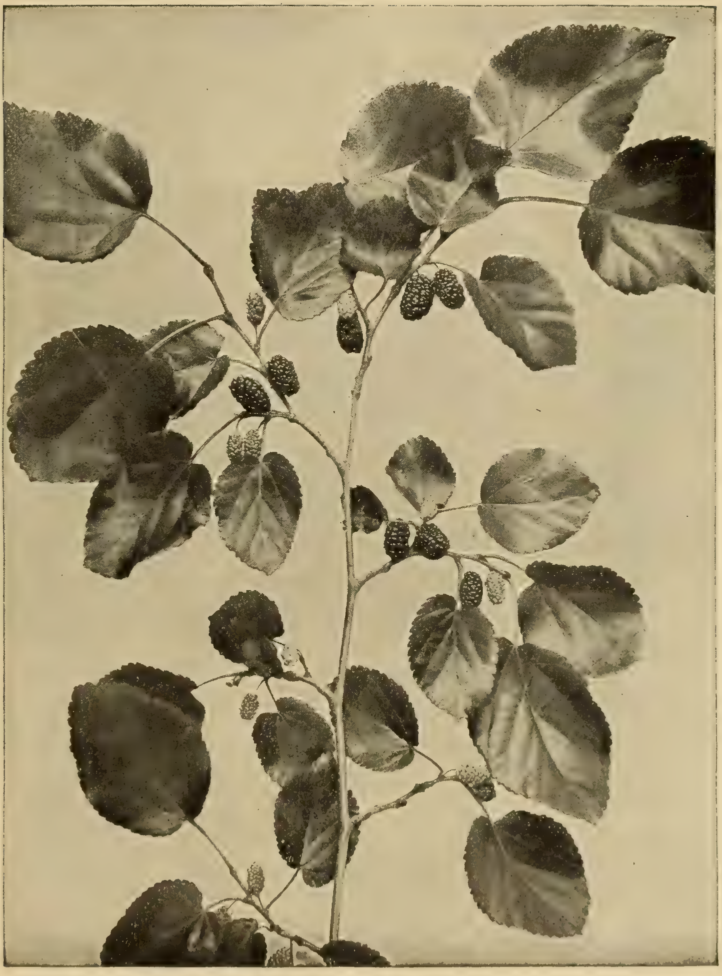
It is called "throwing," and the operators are known as "throwsters." Next the thread is cleaned by running from one bobbin to another, through a slit that will scrape off any lump or nib. Now the raw Silk thread is ready to be doubled, or made stronger and larger. Imagine now that the bobbins of Silk are Silk cocoons, and that the reeling begin anew, save that the reel is another bobbin, for the thread is dry and does not need a reel. As each thread leaves its bobbin to join the cable, it passes through a "faller," which falls down and stops the machine if its thread breaks. Now the doubled or tripled thread is twisted on a spinning-frame, and as it leaves the frame, is wound again on flying bobbins. The Silk-throwster is at liberty to vary his filaments, strands and twists, to please his own ideas of either

worth or trade, and an ordinary three-cord sewing silk thread may be composed of nearly two hundred of the original Silk-worm filaments. It is now ready for the dyer.

What peculiarity has Silk?

It is a remarkable absorbant of water, and will take up from

Fig. 134. CONDITIONING APPARATUS.



A BRANCH OF THE WHITE-FRUITED MULBERRY TREE
(MORUS ALBA)

The Mulberry tree is the first essential of silk culture and has been carefully grown, in many varieties, for three thousand years. The Philippine *variety* has a high reputation, but even other *species* of the tree have been found to be of great or nearly equal value. The worms are fed upon the leaves. After hatching, the little worms crawl up through holes that are punched in the paper laid over them. Their appetite is voracious, and their growth rapid.

1.—THE SILK WORM, Life Size. 2.—Another View of the Silk Secreting Apparatus in the Worm (See Page 357). 3.—Moths, Issuing from their Cocoons. 4.—Cocoons made by Silk Worms. 5.—The Bombyx Mori (Silk Moth).

twenty to thirty per cent. without feeling damp. As it is sold by the pound, its "condition" is ascertained at "conditioning houses," which issue certificates of condition to accompany the goods. The Silk is dried and weighed.

What is the Serigraph?

An ingenious American invention, now used all over the world, by which the grade of a Silk thread is graphically registered. The Silk is wound from one reel to another, but the second reel is three per cent. larger and thus stretches or strains the thread. The thread goes over an agate hook that is fastened to a pendulum. The movement of the pendulum indicates the strain on the thread, guides a pencil on a revolving cylinder of paper, and by wave-lines traces the history of the thread as it went by. By comparing these records, the comparative qualities of various threads become accurately known before they are subjected to wear of any other kind.

Does the raw Silk shine?

No. Up to this point it is dull in color and harsh to the touch. It must be "scoured"—that is, nearly boiled and then bleached. A coating of gum covers the true fibre and this is to be removed, leaving the light to play between the original, single filaments that came from each side of the worm's mouth or spinneret. (See Interference, in chapter on Spectroscope.) About three hundred pounds of thrown Silk are put in two hundred gallons of hot water, with sixty pounds of powdered soap. Here the hanks hang on rods and are turned in the soap-suds. Another "boiling" in a linen bag, with less soap in the water follows, when the hanks are whirled dry in a centrifugal machine. (See Sugar, also Milk.) If the Silk is to be white, it now goes in a closed chamber, where it remains in the fumes of sulphurous acid. After bleaching, it is washed in cold water. From twenty-five to thirty-one per cent. in weight has been lost.

I should like to know about Mourning Crape.

This most peculiar product of the loom is woven from Silk that has not been scoured. The black dye and the gum unite in holding the light. The waves are given to the material after

both spinning and weaving, by various processes that are jealously kept secret, often by means of finishing by one secret method, in one town, what was begun by another secret method in another town. The word *crape* is the same as *crisp*. The light falling into the little furrows of black, is almost completely swallowed up, and thus black crape becomes probably the blackest thing we have. The effect on the visual senses is so notable that many persons are at once deeply depressed by the mere sight of black crape.

What remarkable thing followed in the progress of Dyeing Silks?

The manufacturers desired to get back in weight what was lost by scouring. The readiness of Silk to unite with chemicals opened a wide field for this enterprise, and at last the dyers have been able to so use the metal or Element, tin, as to add forty ounces to the pound of scoured Silk, one hundred and twenty ounces to the pound of Silk dyed in the gum, or unscoured (called *souples*), and one hundred and fifty to spun (waste) Silk. This practice began with the metallic "heavy black Silk" which the housewife dons on great days, and ended with the white Silk handkerchiefs, which twenty years ago were so soft and to-day are so greatly changed in feel.

I hear of Artificial Silk.

Yes. It is but logical that the chemists, having a pure carbon compound (see Chemistry) to deal with, should proceed to satisfactory results. In the chapter on Compressed Air, we have noted the means by which artificial Silk-like filaments are projected from small tubes. Dr. Lehner, one of the many experimenters, obtained a cellulose solution free of explosive nitre and sufficiently viscous (or ropy) to be drawn out in filaments as fine as the Silk worm's. These are gathered and reeled into thread, the thread into yarn, and the yarn is woven into cloth. The mulberry forests and worm-hatcheries, with their problems of climate and disease, are omitted, and old rags, wood-pulp, and acids take their place.

What is the quality of this Artificial Silk?

About sixty to seventy per cent. as good as the best, real

scoured Silk woven stuffs. An English conditioning official certifies, first, that it *is* artificial; that it is about seventy per cent. as strong and flexible as real silk; that it is much evener in texture; that it takes the dye with perfect brilliancy and evenness, and that this applies to all shades of color.

What was the Mulberry speculation?

About 1837, four of the New England States were giving bounties on American-made Silk, and Congress debated the subject of national aid. In 1838, mulberry trees sold for ten dollars each. In 1839, the trees sold at three cents each, and most of the nurseries were abandoned. The Silk industry languished for many years thereafter, while the French producers remained masters of the situation.

What are the peculiarities of the Silk Worm?

The common *bombyx mori* has been in the hands of man for many thousand years, and, under this domestication, has become an obedient but unhealthy creature. After hatching, it asks only for food and a place in which to wind its cocoon. But this subserviency to the will of man has made it the easy prey of parasites, and at times the existence of all the French worms has been threatened. It was one of the triumphs of Dr. Pasteur, of Paris, that he discovered the cause and the possible prevention of the greatest danger that ever confronted the manufacturers of the Mediterranean countries. There are very many Silk-worms other than the *bombyx mori*, but less than ten kinds have been successfully bred for commerce.

What is Satin?

Satin is, first of all, a Silk fabric, because of the sheen of the Silk filaments. If a scoured thread be laid across the light, it will shine at its best. In a loom the threads are crossed, as the splints are crossed in a basket. If we take four yards of carpet a yard wide, there are threads four yards long, running the long way. This is the *warp*. The threads running across the carpet are the *woof*, or *weft*. The weaver calls the whole carpet the *web*. Of course, it is the short threads that are put through the long ones—that is, shuttles carry the *woof* across the carpet. Suppose, instead of carpet, we are weaving Satin. Our effort

Fig. 136. SILK WORM REARING ESTABLISHMENT.

now will be to keep the warp on the under side, and let long stretches of the *woof* shine in the light, without letting the *warp* cross them and break the light. To do this, only every seventeenth warp-thread is raised—that is, as the woof-shuttle goes through the warp-threads while they are spread apart for that passage, 940 warp threads will be below and only about 60 above—only just enough to hold the woof in place. But a different warp-thread rises for this upper service every time. At the edge of the Satin, called the *selvedge*, where strength is necessary, you may see the regular weaving. In Satin, the light effects, from precisely the same material, are astonishingly different. Satin dresses and linings have two advantages over all other Cloths. They do not harbor dust, and they offer little friction.

Did all the Chinese once use Silk?

Probably. Ancient history shows that the garment was held as an article of great value. The Chinese wore the garments of their ancestors, generation on generation.

How generally was Silk worn in Europe?

About the middle of the fourteenth century, one thousand nobles of Genoa walked in a public procession, all clad in Silken robes. Our theatres, in their plays of the *ancien regime* (time of Louis XV. or earlier) show the costumes of the upper classes. Beside coat and vest of Silk, the *culottes*, or breeches, were also of Silk, usually white. The peasants, who wore longer coverings on their legs, were thus *sans* (without) *culottes*.. They grew proud of the designation, and with the French Revolution there disappeared the Silken wear which had distinguished the upper classes.

What Silken Garment has attracted public notice in recent times?

The skirt of the female dancer. In the skirt dance, the voluminous folds of a silken fabric are displayed by movements of the hands, and stereoscopic pictures are often thrown on the moving disk of silk which surrounds the dancer. It is not uncommon to employ 500 yards of silk in a single skirt, which does not then

appear "full" on the wearer. To develop this fabric toward the full possibilities of the silken fibre, for theatrical purposes, has been the study of managers, and even Mr. Edison's talent and advice have been sought. It is said of the women of the Greek island of Cos, that they clothed themselves in silken garments that were of almost incredible thinness. It is believed that the Chinese weavers will be set at work on fabrics for skirt-dancers that will be made from the original filament as it leaves the silk-worm's mouth, but scoured of one-quarter of its weight. In this way a thousand yards of "Cloth" might weigh but a few ounces.

How old is the Loom?

The loom for plain weaving is represented in the Egyptian monumental paintings and on Greek vases. We have, in *Records of the Past*, vol. 3, p. 151, the following, where the poet bewails the misery of the "little laborer:" "The weaver, inside the

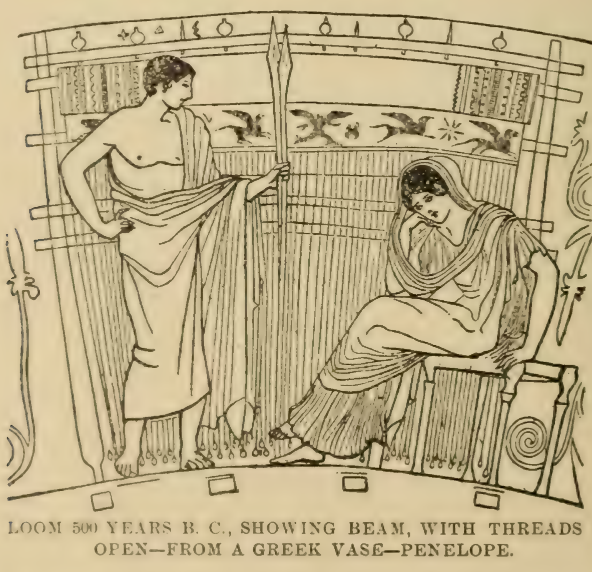


FIG. 137. LOOM 500 YEARS B. C., SHOWING BEAM, WITH THREADS HANGING OPEN—FROM A GREEK VASE—PENELOPE.

houses, is more wretched than a woman; his knees are at the place of his heart; he has not tasted the air. Should he have

done but a little in a day, of his weaving, he is dragged as a lily in a pool. He gives bread to the porter at the door that he may be allowed to see the light." This poem may be 5,000 years old.

How did the Loom evolve?

The frame first held only the warp, which possibly hung between two trees. Then it was placed vertically before the weaver on a frame, and the Turks still prefer to make their often beautiful and always valuable and durable woolen fabrics in this manner. A Turkish weaver stitching with needlefuls of his

Fig. 137½. TURKISH WOMEN WEAVING RUGS.

various *woofs* on a frame of *warp*, has long been a familiar spectacle, furnishing an instructive method of advertising in the city store windows of America.

Mention an ancient reference to Weaving.

In the Book of Job: "My days are swifter than a weaver's shuttle"—chapter 7, verse 6. This is the Protestant version. The Catholic version reads, probably with more accuracy: "My

days have passed more swiftly than the web is cut by the weaver." The Desert of Gobi or Jobi, and the Lake of Lob in Turkestanese Asia, are possibly connected with Job. We may attribute almost the highest antiquity to the Book of Job.

How recently did the Loom leave the houses of the people and retire to the factories?

Many of our fathers and all our grandfathers can recall the time when every hamlet, however small, possessed at least one

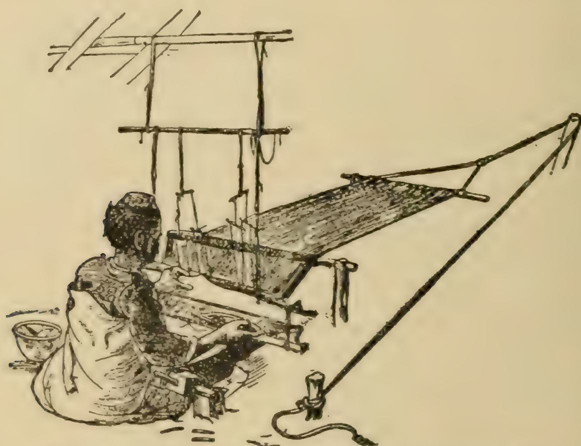


Fig. 138. LOOM OF AN EAST INDIAN, STILL IN USE.

loom, where rag carpet was woven. But, since 1840, the Cloths used by the people have usually been made far from home, and all wise, industrious and frugal inhabitants have found life much more easy and comfortable.

For what inventions in Cloth-Making were the Eighteenth and Nineteenth Centuries famous?

In 1745, John Kay invented the fly shuttle, whereby, when the *warp* was spread apart into the "shed," the shuttle shot across, leaving a trail of *woof* behind. In Napoleon's time, Jacquard invented his wonderful cards, whereby a loom could work on a beautiful pattern as rapidly as on plain Cloth.

TAKING MOTHS FROM COCOONS AND LAYING THEM ON PAPER TO BE MATED.
THE FEMALE THEN LAYS EGGS.

THE EGGS HATCHED INTO WORMS. THE WORMS LAID IN BASKETS, TO BE FED ON MULBERRY LEAVES.

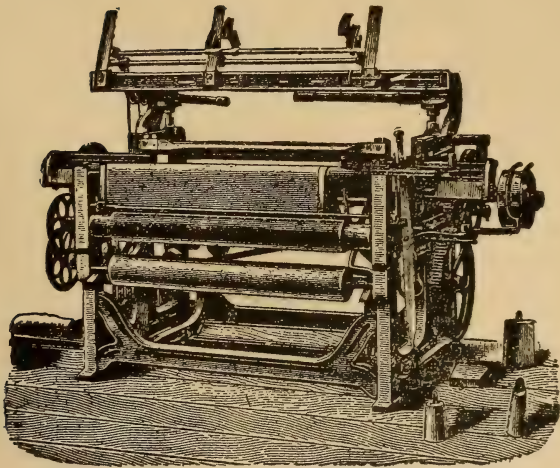


Fig. 139. POWER LOOM.

Tell me about the Jacquard Loom.

First, the ordinary loom must be more carefully described, but, in a few words, the principle of Jacquard's loom was a chain of pasteboard cards, each with holes in different places. Certain rods would be let through these holes, and other rods would be held back or down. This principle has been applied to the mechanical musical organs that to-day excite so much admiration, and the telegraphers have at last taken advantage of the same idea in the scheme of automatic telegraphic transmission that we have described in the chapter, Electricity.

What are the main parts of an ordinary, ancient Loom?

1. There must be two rollers—the warp beam, on which the warp threads are reeled, and the cloth-beam, on which the finished cloth is received.

2. There must be two heddles or healds, which we may liken to combs, merely to show that the warp threads pass by them, as a comb allows hair to pass by its teeth. Suppose every second hair were fastened to a tooth of the comb, and there were two combs, similarly established, then, if one comb were raised, a "shed" would be formed, through which a thread or

cross-hair could be carried. The heddle is not a comb, because it is closed at bottom and top, and its slats or threads each has

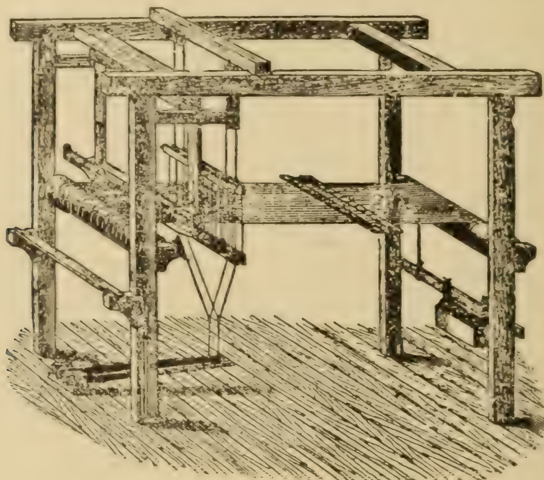


Fig. 140. HAND LOOM.

a hole or eye for the *warp* to pass through. A treadle or lever raises or lowers either heddle, and now one may rise while the other sinks or stands still, and *vice versa*.

3. There must be a reed, a comb—a thing like the heddles, but with a warp *between* every tooth. Attached to this comb is a "way," on which the shuttle, holding and paying out the *woof* can slide. After the throw, or pick, or slide has been made, and the shuttle has landed on the other side—always with a click—the reed is pulled toward the weaver and the new thread is beaten or battened up against the other woof-threads that have been thrown across before. Thus, every cross-thread of every piece of Cloth or carpet represents not only the careful process of making the thread itself (as we have shown in Silk), but as it passed across in the loom, the machine was stopped while the thread was pounded up against its fellows, and the Cloth made firm.

Are all modern Looms noisy, and why?

Yes, because the shuttle bearing the spool of thread must be

thrown across through the shed. The shuttle in your sewing machine at home makes the same noisy journey. More force must be used than is needed for the bare journey, and the noise is nature's notification of the change of motion into heat or other forms of action. Also, the shuttles must be changed, and as they must always be free, so that they can be thrown, with only a trail of thread hanging or paying out behind, they rattle and make extra noise. Machinery Hall, at the World's Fair of 1893, had a noisy section, whose very rumpus seemed to gather sight-seers, who for hours watched the ribbons, Cloths and souvenir Silk book-marks or badges come from the Jacquard looms. Probably the first Jacquard loom ever seen in the West was exhibited in the Inter-State Exposition at Chicago in 1875.

Proceed to these Jacquard Cards.

It is unnecessary to give the precise action of these cards, for they are simplified each decade; but, by their use, every thread of warp may be separately lifted; although, where a picture on a badge has been studied, certain recurring combinations of warp can be lifted together in a "leash." But let us suppose a score of music—"Home, Sweet Home"—is being portrayed on the badge, and the blue thread is to pass across so that it will show on the surface of the badge in all the letters of the title. Then, in practice, all the warp threads that are to hold down blue woof threads will be raised at once, and all these warp threads will hang on one rod that goes up into one hole of the pasteboard card that at the moment stops over the loom. For a small badge a very long chain of cards, nearly all differently punched with holes, is necessary, nor is the attendant arrangement of colored threads on shuttles, to be thrown at the opportune moment, less complex. The Jacquard loom, clicking out its always beautiful pictures, with the finest Silks and most brilliant fixed colors, justly challenges the astonishment and admiration of all who see it, or see its products. The pattern-makers, who compose new combinations and make successful chains of pattern-cards, necessarily command high rewards, according to their ingenuity.

How was Velvet, or Velvet Carpet first made?

There were two warps, one for the velvet (the pile warp), which was much longer than the plain warp. That is, there were two warp-beams or cylinders to roll the warps on, and one cloth beam to hold the finished velvet. At say every third shoot or pick of the *woof* across, a shed was made of the upper or velvet warp and a wire with a groove running its upper length was put across *instead* of the *woof*. This wire raised up a row of loops; then two more regular shoots were made and another wire was put in. When the wires were needed for use again, a knife called a trivet was run along, following the groove in the wire, and the loops were cut, forming the pile which we see in velvet. In Brussells carpet and "Terry velvet" the loops were left uncut. A double-web plush may be woven by running two warp-beams or cylinders in connection with the velvet warp-beam. Thus the weaver has a cloth-web above and below. By attaching the velvet warp, which may of course be a double or triple untwisted thread—three threads—from one web to the other, the two Cloths thus woven are attached to each other by the threads of the velvet warp—no wire being used. Now the two Cloths can be cut apart or split, and there is a velvet-pile left on what was the inside of each Cloth. But we shall return to the subject of carpet-weaving anon.

How are Chinchillas and other heavy overcoatings made?

The chinchilla is a small rabbit-like rodent of South America, whose fur is used by the natives for wool, and prized by other countries for muffs, etc. To secure the appearance of fur on the loom, the yarns may be soft and large, there may be several warps, and several woofs, and the cutting of the loops may be done with knives that leave a furrow behind. Every warp-beam or cylinder gives employment to two heddles that lift half and depress half the warp-ends or threads. If there are two warp-beams, there must be four heddles, and with heavy yarn, four heddles will produce a very heavy double-cloth or overcoating. The process of milling and felting, yet to be described, also play a most important part in the appearance of heavy and costly Cloths.

Then Weaving is not the only way to make Cloth?

No. Cloth may be felted or matted together, as in hats. It may be looped from one thread, as in knit goods; or, it may be braided, where the warp is looped together without any woof—as in our bindings.

How is Gauze woven?

It is a species of braid, but has also a woof thread. In front of the two heddles or warp-lifters of an ordinary loom is another heddle called a *doup.* This little heddle catches every second warp-end, and twists or turns it, say, to the left, one thread's width. The result, after the reed has battened up the woof on the web, is as follows: A shed has been formed; the woof has shot through; the top warp has gone down, looped under the bottom warp, and immediately risen again, instead of remaining to form the bottom part of the next shed. By this loop, the woofs are held further apart, and gauze is the result. In most sorts of mesh-work, the starch is the principal thing. The housewife washes her lace window curtains, starches them heavily, and dries them on *stretchers,* thus demonstrating the power of the stiff threads to hold the mesh of the lace in place. The fisherman spreads his net.

The variations of Weaving must be infinite in number.

Yes. With a heddle for each warp-thread, attainable in the Jacquard loom; with devices that change the shuttle as often as need be, supplying a different woof each time; with variations of material for upper and under sides; with even the ordinary number of heddles for double Cloths, the variations to be attained on the surface of the texture are innumerable, thus giving to the weaver not only a school of patience, but a field of invention. The lace machines, by hanging warp and woof from the same beam, still further enlarge the varieties of mesh that may be woven.

What is Cotton?

It is a downy substance, usually white, which surrounds the seeds and bursts from the seed-capsule of a low mullein or mallow-like herb—in America the *Gossypium Barbadense.* The culture of this plant supplanted the culture of indigo in America

early in the nineteenth century; and, since 1850, the commonwealths that border the Ocean and Gulf have been known as

Fig. 141. THE COTTON FIBRE UNDER THE MICROSCOPE

Cotton States, and nine million bales, each weighing 500 pounds, have come to be considered a fair annual crop.

What is the history of Cotton?

Herodotus, in his description of India, 400 B. C., says the people "possess a kind of plant, which, instead of fruit, produces *wool*, of a finer and better quality than that of the sheep; of this the Indians make their Clothes." Columbus found Cotton growing in America, and it was better than the Indian Cotton. Dr. Livingstone found Cotton growing wild in Africa. Cotton was grown in the southern parts of ancient Egypt, but Linen was the material favored by the priests. In ancient Mexico, the down of Cotton and the fur of chinchillas, etc., were woven together. In Peru, the mummies of the pre-historic age were wrapped in Cotton. All the ancient world, except China—that is, Mexico, Egypt and India—had Cotton Cloths that were dyed with indigo.

Was not Cotton known in China?

It seems not. Arabian travelers of the ninth century, A. D. recount that every one in China was clothed in Silk. The

Tartars introduced Cotton, and now a *blue* Cotton shirt is the outer garment of every Chinaman who is not rich or powerful.

What did the Spanish Moors do for civilization?

They transplanted the Cotton plant, rice, sugar-cane and the Silk-worm from the east to Spain in the tenth century, and Cotton was woven for sail-cloth and other purposes where weight and coarseness were required. But the Christians refused to learn at once of the Moslems, and it was long after the Crusades that "Cotton wool" was used by the weavers of Northern countries.

What obstacle was in the way of using "Cotton-Wool"?

It was full of seeds. These were picked out slowly, until an American—Eli Whitney—while on a visit to a Southern friend, noted the need of a machine to get rid of the seeds, and by introducing saws that played between the wires of a fine grating, pulled away the wool while the grating held back the seeds—thus making the celebrated Cotton-gin, the *gin* being a corruption of *engine.*

Were the Cotton-Seeds valuable?

They were then thought to be worse than valueless. But, with time, Cotton-seed oil and cake have come to be products of enormous value. In years of corn famine (as in 1895), the use of oil-cake for animal-feed was widespread, and, at the great packing-houses, both butter and lard are mixed with the oil, and thus find a ready market under various trade names that reveal the presence of the Cotton seed oil. For animal-feed, the oil-cake is pressed after the seeds have been hulled or decorticated. We are unable to name any other plentiful substance, once so lightly esteemed, that has assumed so much importance as Cotton-seed in the commercial world.

All Cotton must be spun into yarn?

Yes. On investigation, you will find that spinning is the leading branch of the trade of cloth-making. Spinners develop the rarest skill and receive high wages. Spinning machinery is most complicated and difficult to manage and tend (or *tent.*) This brings the spindle before us. Next to the ax, knife and bowl,

and before the needle, comes the spindle as an implement of mankind. It was originally as it is to-day. Next, it was made with a hook or notch (like the crochet-needle) in its point. Then in the centre was hung a round stone for a wheel or balance. The fibre to be spun was caught by the notch ; the left hand receded with the bunch of fibre or wool ; the right hand rolled the stone on the knee ; the spindle revolved; the yarn twisted ; the two hands then wound the made yarn on the spindle, and thus the measure of yarn called "the spindle" was first established. The famous Cotton muslins of India are made from yarn that is spun on a bamboo spindle no thicker than a darning-needle, weighted with a pellet of clay. The fabrics thus composed, are so light that they are not improperly named "woven air." In the remote regions of Scotland and Europe as well as in Asia, the hand spindle has never been displaced.

What improvements have been made on the Spindle?

None. To make a yarn from a body of short fibres, the substance must still be drawn out or toward a revolving point. To operate the spindle, however, four things have been accomplished. First, it has been made to revolve faster and more continuously, as in the spinning-wheel; second, the drawing-out of the fibre has been given into hands (rollers) of iron; third, flyers have been added ; fourth, inasmuch as the same wheel might drive more than one spindle, great numbers of spindles have been joined in one machine.

What, then, is so wonderful about Cotton manufacturing that it has long taken the labor of weaving out of our households?

It is the union of a number of machines that not only spin the yarn, but prepare the fibre for rapid spinning.

What machines precede the real Spindle?

1. The opener; 2. The scutcher and lap machine; 3. The carding engine; 4. The combing machine; 5. The drawing frame; 6. The slubbing frame; 7. The intermediate and roving frames.

Fig. 135. JAPANESE SILK OPERATIVES FEEDING SILK WORMS.

DESTROYING THE CHRYSALIDES AND REELING THE COCOONS.

What are the real Spindles called?

Frames, or jennies and mules. The throstle frame of spindles spins coarse warps. The self-acting mule, the hand-mule, the doubling frame and the mule doublers and twiners make both coarse and fine yarns.

Define some of these terms.

To *card*, is to comb, as you would card a horse. To card Cotton, Wool, Silk, Flax or Hair, lays its fibres parallel and brings away some dirt or foreign substance, if there be any in the fibres. To *scutch* and *lap* is to beat, blow, clean and, in Cotton to produce Cotton batting or bat. *Mule* is German for *Mill. Roving* and *slubbing* both mean a drawing out and a slight twisting at the same time. *Throstle* is the name of a spinning machine where the spindles revolve on a stationary base, while on a *mule* (mill), the spindles themselves may revolve on a movable base. For the result is the same whether the fibre move away from the spindle, or *vice versa.*

Describe briefly the Cotton process that precedes the real Spindles.

The Cotton, seedless, from the bale, goes into the *opener*, which blows, beats and passes it to the *lapper*, which flattens it

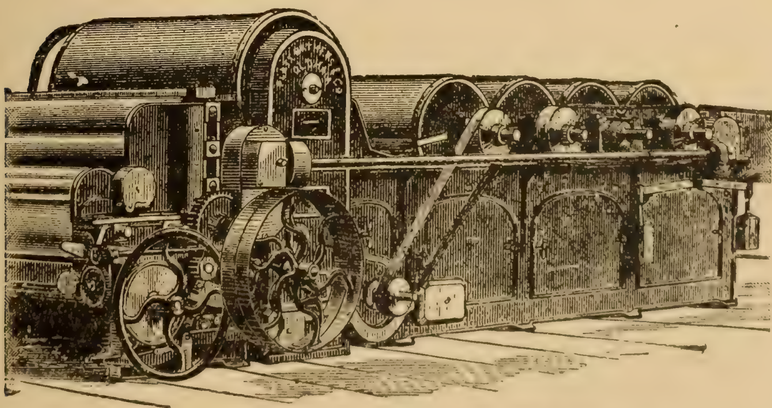


Fig. 142. THREE-CYLINDER COTTON OPENER, BEATER AND LAP MACHINE.

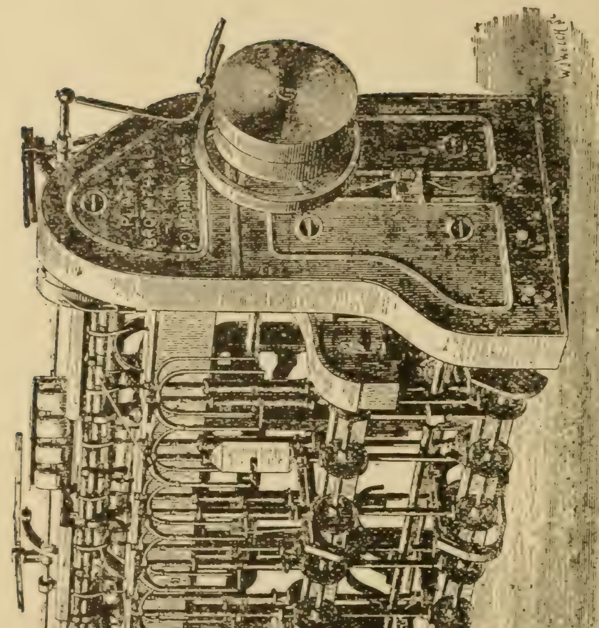


Fig. 143. COTTON SLUBBING FRAME.

and prepares it for the *scutcher*, another beater and purifier. These are large steel machines, with shafts rapidly revolving by steam-power. The Cotton in laps now goes into the *carding engine*, another large steel machine, which has a toothed cylinder, with smaller toothed cylinders revolving the other way. After passage through this process the Cotton, now an airy fleece, enters the *combing machine*, passes into a funnel which narrows it, through rollers that flatten it, and coils as "slivers" into a can that awaits it. The can of slivers is now taken to the *drawing-frame*.

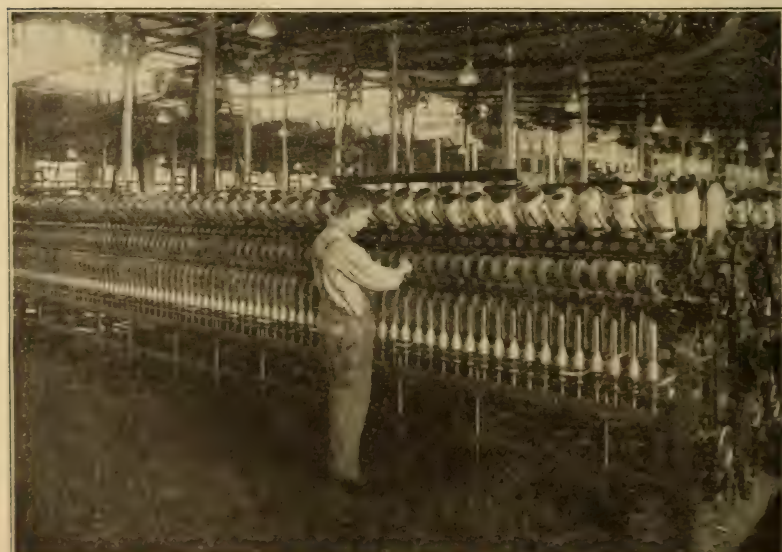
Describe the Drawing-Frame for Cotton.

By passage between four sets of small rollers, each set revolving about six times faster than the set behind it, the slivers of Cotton-fleece are drawn out to a considerable length. The lower in each set is fluted lengthwise and the upper one is covered with leather, to enable it to hold well to the Cotton. Many slivers are fed into the drawing-frame at once, and the mess comes from the machine about twelve hundred times longer than it entered.

Where does the sliver of Cotton now go?

To the *slubbing* or *twisting machine*, which has a preliminary spindle, and a bobbin to receive the slightly twisted sliver. The slubber has three sets of rollers or stretchers. Great numbers of original slivers are now in the sliver that is stretched and slightly twisted in the slubbing frame. From the bobbins of the slubber the twisted sliver goes to the stretching rollers of the *intermediate-frame*. Here the slivers are again doubled. As these frames come, each has more spindles. We now arrive at the *roving* (twisting) *frame*, merely another and last set of the roller-stretchers, with seldom less than one hundred spindles. When the sliver or rove is on the bobbins from these spindles, it is ready for spinning in fact. It must be understood that different spinners may use a different series of stretching-apparatus. They may combine the rollers in fewer or separate them into a greater number of machines.

WOOL—DRAWING IN WARP THREADS.



WOOL—CAP SPINNING.

What state is the Cotton now in?

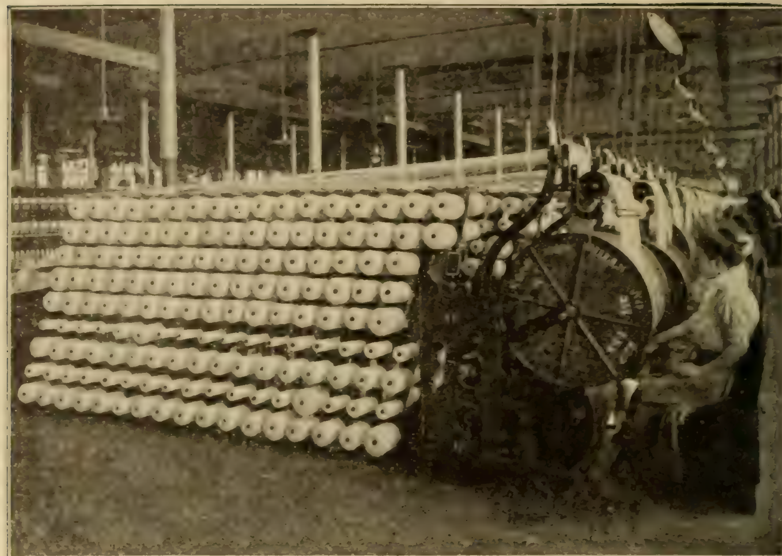
It is a fine, fleecy, *roving*, or slightly twisted string, incapable of bearing much strain, useless as *warp*, but if further elongated, it might be used as *woof* (or *weft*). It now goes either to Arkwright's *throstle*, or to Hargreave's *jenny*—or to combinations of the two machines.

What was Hargreave's Jenny?

He saw a spinning-wheel fall over. The fly-wheel was going rapidly, and the spindle standing vertically continued to whirl, while the flax continued to twist off its point. So he set up a row of eight spindles, turned them all by one wheel, and with a long holder, drew flax away from them all at once. This he called a spinning-jenny, *jenny* being the word for a little engine. The spinners, believing his jenny with its eighty spindles (as afterward enlarged) would starve them, mobbed him. With this jenny, only *woof* was prepared. The warp was always of Linen threads.

What did Arkwright do?

He made the *throstle*, and all the roller machines called frames that have been here mentioned. He called it spinning by rollers. He grasped the idea of elongation in this manner while seeing a bar of iron stretch out while passing through the rollers, and obtained the same effect by having two sets of rollers, the forward ones going faster than the rear ones. In this way the Cotton was stretched out. Now, if we mount a stretching set of these pairs of rollers on a frame, set before them a row of bobbins, and take off each of the bobbins and end of the prepared Cotton—the *sliver*, or the *roving*—then we will be stretching many yarns at once. We may now lead the yarn down to the point of a spindle which is whirling with great rapidity. Here by the action of flyers, or little arms which go around with the spindle near its point, carrying the thread with them, the thread is twisted and pulled toward the bobbin, which surrounds the spindle, and the bobbin is made to evolve by a passing belt of cloth that rubs against it. With this throstle,



WOOL—BEAMING AND YARN INSPECTING.

WOOL—RING TWISTING.

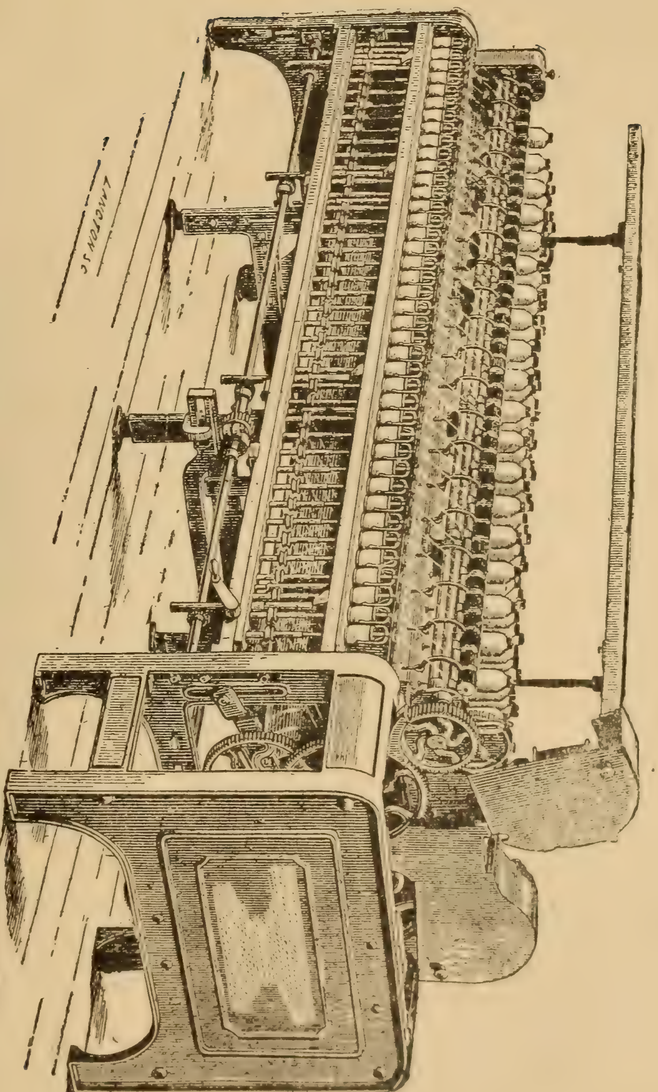


Fig. 146. THE THROSTLE, WITH SPINDLES AND FLYERS, FOR COARSE COTTON SPINNING.

nearly all ordinary *warps* are made, but it is not used for fine threads. Of course, the throstle was mobbed worse than the jenny.

Suppose our roving go to the mule-jenny instead of the throstle?

The mule is a return to the Hargreaves idea of pulling the yarn *off* the very point of the spindle. Arkwright's rollers are used and are stationary. A moving carriage, holding a great number of spindles travels away for two yards from a set of Arkwright's *throstle*-rollers. The carriage goes much faster than the *roving* comes from the rollers. The spinner watches each yarn with a skill that can only be obtained in years of service, and when the carriage is far enough out, the rollers stop while the carriage comes back—as in a single-cylinder printing-press or a saw-mill. Whether this *mule* be hand-*tented* or self-acting, it makes the hardest and finest yarns.

Was the English Government jealous of the possession of these machines?

Yes. None were exportable, nor could a spinner, or one acquainted with the throstle, mules, or carding engine emigrate, even to America. All out-going baggage and mail was searched for models and plans, and a model was actually seized in a trunk at a custom house. Nevertheless, the secret reached America at an early date. Now there are vast Cotton mills, both in China and Mexico. The actual secrecy of all the trades is, even to-day, a matter worthy of observation.

What were the benefits of the mule-jenny?

From a pound of Cotton the spinners had obtained two hundred and one thousand six hundred feet of yarn, or eighty hanks of eight hundred and forty yards each. By Crompton's *mule-jenny* it was possible to spin a pound of the same Cotton into eight hundred and eighty-two thousand feet of yarn, or three hundred and fifty hanks of eight hundred and forty yards each.

What is our Sewing thread?

Usually a cable of six cords of yarn. It may be three, four or

A JAVANESE SILK LOOM.

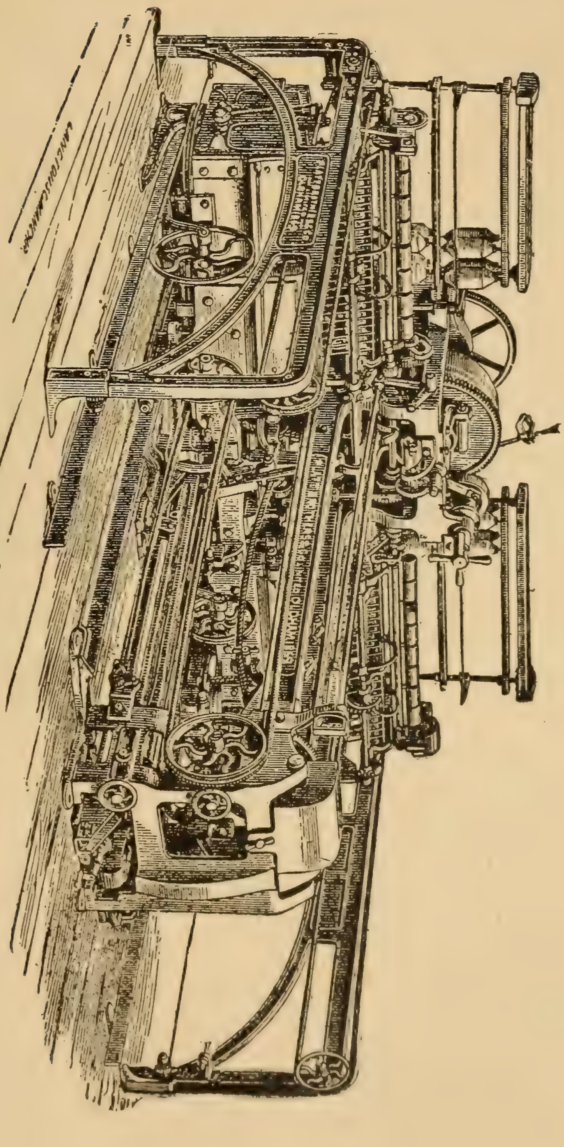


Fig. 147. SELF-ACTING MULE, FOR FINE COTTON SPINNING.

six cord. It is numbered according to the twists these cords get to the inch when they are put together. The thread-twister has usually purchased his yarn from the spinner, scoured it,

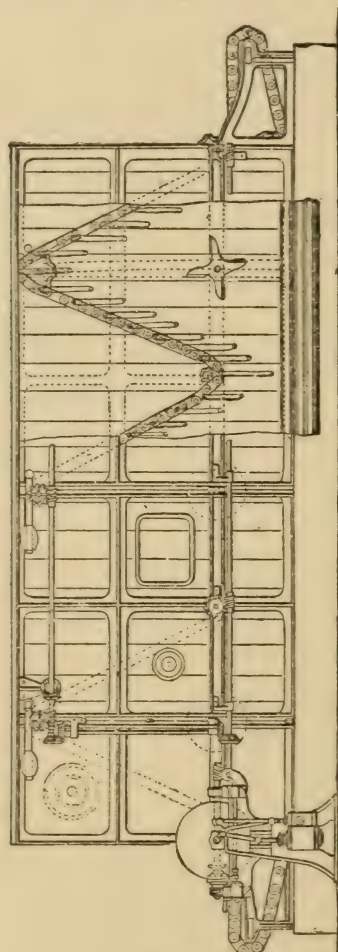


Fig. 148. CONTINUOUS HANK DRYING MACHINE. (COTTON.)

reeled it like silk from the cocoon, doubled it into two-cord, twisted the two-cord, then tripped the two-cord twist and twisted that. It is then bleached, like Silk and starched. The

spools are made by machinery. At the World's Fair, there were exhibited machines that did really all the work of getting the thread on the consumer's spool, and labeling it for market.

Why was Cotton Thread made so strong?

Originally, because the shuttle or hook of the sewing machine gave the ancient thread a strain that it would not bear. Thus the machines make for themselves an infinitude of labor.

Where did our wooden spools originate?

The Glasgow and Paisley thread-makers—J. and P. Coats operated at Paisley—took ash and birch, dried it and cut it into cross sections called blocks. Coats invented a blocking machine. With these blocks self-acting lathes can be used, and the spools can be made as fast as they are needed.

What is Cotton crochet-thread?

It is only unstarched Cotton six-cord thread, as you may observe by taking it apart. The yarn was not stretched out in the *roving*, but the fibre was very fine. The soft *roving* has been twisted, then doubled and then the double has been tripled. This makes a beautiful cord, much like Silk, and chemically not greatly at variance with Silk.

We are now back to the Looms. Is not our cheap Lace woven on the Loom?

Yes. On *a* loom. The bobbin-net or Nottingham lace was invented in England, and had no prototype in India. The lace loom as first operated at Nottingham, England and Calais, France, bears but little resemblance to our old-time looms. The beam or cylinder that holds the web of finished lace is above the reed, and *both the warp and woof threads* are fastened to it at the beginning. The *woof* threads swing like a pendulum. The Jacquard cards are used to give the pattern on the lace. When lace was first woven by the knitting process, and the gimp-thread worked patterns on top of the net, the gimp-thread jumped from one pattern to another, leaving a trail of gimp-thread. This was cut away by children. Lace which answers every purpose of decoration is made on the machines at less than one-twentieth

Fig. 150. A LACE MAKER AT WORK.

of the very low prices paid for pillow-lace. Of course, the *quality* of the material may be the same.

Has Loom-Making prospered in America?

Yes. At the World's Fair the exhibits were very fine. Ribbons were made in solid colors; twelve Jacquard looms were run with one set of cards. Looms were run with paper cards, iron roller cards and iron bar and peg cards. A loom company at Worcester, Mass., manufactures power looms for worsted, woolens, dress goods, flannels, blankets, jeans, ginghams, upholstery, draperies, shawls, jute carpets, ingrain carpets, silks, velvets, satins, burlap, jute bags, ribbons, suspenders, bindings, etc. A branch of this house at Dobcross, Eng., has made over ten thousand looms for foreign use.

What are the chief uses of Cotton Cloth?

For the underwear and bedding of the people. In temperate climates, the outer summer-wear of the women is chiefly woven of Cotton *warp* and *woof*. The white shirts of the Caucasian race are nearly all Cotton. But in very hot climates, white Cotton becomes the main wearing apparel, as it has the minimum of receiving capacity for the heat leveled at it by the sun. If, therefore, we consider the shirts, underskirts, sheets, pillow-cases, comforters (as we call these in America), calicos, muslins, cambrics, Canton flannels, etc., that go to make up the wardrobe of the human race, not to speak of the Cotton warp that underlies so much of our Woolen wear and carpets, we shall see that the Cotton-silk, bursting from its seed-pod, is one of the most important things with which civilized man deals. Its manipulation and sale have sensibly altered the habits and relations of the human race.

What is Calico?

It was first a printed cotton cloth brought from Calicut. This was an Indian city, once called Calicoda, because the first monarch gave to a chief a sword and all the land around the temple from which a cock's crowing could be heard—Calicoda meaning *cock-crowing*. In England, *Calico* still applies to white Cotton. In France, printed calico is called (cloth) *Indienne*, and in Italy,

Indiana cloth. In the United States, Calico is Cotton cloth printed in colors with inks or dyes.

To what may Calico printing be likened?

To the printing of daily journals from rolls of paper. From 1865 until the 70's, when the ten-cylinder Hoe press was in vogue, the similarity was striking, although in those days a roll of paper was not used. In a Calico-press, there may be eighteen little cylinders surrounding the big one. The little cylinders are of copper and the part of the Calico-pattern that each cylinder is to impress has been graven in the copper with acids, or by pressure from a steel cylinder. These cylinders form an expensive feature of the plant of a great mill. The color or dye is served to the cylinder from a trough, and the cylinder is scraped by a *doctor* (conductor). The roll or web of cloth goes through this press as a roll of newspaper or wall-paper would go.

What are the preliminaries of making Calico?

The cloth must be singed—the down must be burned off by passage over a hot plate, or it may be cut off with rapidly-acting knives. It must be bleached, boiled, washed, then again bleached, boiled, washed, etc. It then goes between heavy rollers and is "calendared." It is now ready for the press (machine) and the dyes and mordants.

What is a Mordant?

Mordere, in Latin, means *to bite*. A mordant like tin in the dye-house and in chemistry, is a compound whose molecules have the same affinity for the carbon-compound called the Cotton fibre that they have for the carbon-compound called the dye-stuff, thus making the three molecules into one molecule that cannot be easily broken up.

What is the modern process of printing Calico?

By means of the aniline dyes (see Chemistry), the mordant may be mixed in the same dye-box with the color, and the two go on the cloth under the same cylinder. Thus, where aniline colors are used, the cloth comes off the press, where it has been entirely printed with dyes that were each mixed with mordants. It then enters a long steaming oven, travels slowly to a

roller, folds back to another roller, then forward over another, and then down into a wagon that is ready to receive it and be let out of the chamber. One chamber will steam twenty-five thousand yards a day. The steam drives all the molecules of the cloth dye and mordant into permanent union.

How are the pigments or painters' colors fastened to the Calico?

An albumen is mixed with the insoluble powders that painters use. This goes on the cloth, and when the cloth is steamed, the albumen coagulates and itself becomes insoluble. The albumen adheres to both the fibre and the powder, and the cloth is in reality *painted*, like the front of a house. As the steam process has displaced nearly all other methods, we need not describe the old dye-vats, madder styles, padding styles, resist styles and discharge styles.

How is the steamed Calico finished?

It must be stretched in breadth, chlored (with chlorine), starched, dried, dampened, calendared, and plaited into a book for market. *Book* is from beech-board in German, which denotes the board around which the bolt is wound. Many of these processes are the same for white goods, Calicos, muslins and other goods. Weight and gloss are given to the face of the cloth.

Describe some of these processes for finishing Calico.

After passage through the stretching-machines the cloth goes to the chloring machine, where the under one of two rollers dips into chlorine water and wets the printed calico, which then enters a steam chest, where the action of the chlorine is instantly arrested. This momentary bleaching has brightened the white ground, without dimming the colors. Now the cloth goes through rollers and over hot copper cylinders.

How is the Calico starched?

By a device very similar to the chloring machine. The lower roller dips into boiled starch, egg, or a like mixture, and carries the mixture up to the cloth. This goes up into another pair of rollers and gets well saturated. The cloth is dried again on hot cylinders, and dampened for the final calendaring, or pres-

sure between cylinders. The plaiting machine may fold the Calico around the board. The books are pressed under a hydraulic machine. It is said that the Calico works use forty million eggs a year.

What is Wool?

Wool is the hair of an animal. It differs from the fibre of Cotton or Silk in its mechanical structure, having small outjutting hairs, and it is for this reason that it can be felted, as the little hair-twigs catch with one another. And the natural felting, more or less, of *all* Woolen cloths is the characteristic which marks them apart from Silk, Cotton and Flax goods. The

Fig. 151. THE WOOLEN FIBRE, UNDER THE MICROSCOPE.

sheep, goat, llama and other animals furnish our Wool, but mainly the sheep. The Wool is washed, scrubbed, bleached, oiled, scribbled and treated like Silk, Cotton and Flax. Wool is warmer than Cotton, stronger, and will absorb more moisture. In cold climates it is used in cloth for undergarments covering the entire person except the extremities, and on account of the protection it affords from incoming heats, many men prefer to wear it in the very hot weather of northern climates.

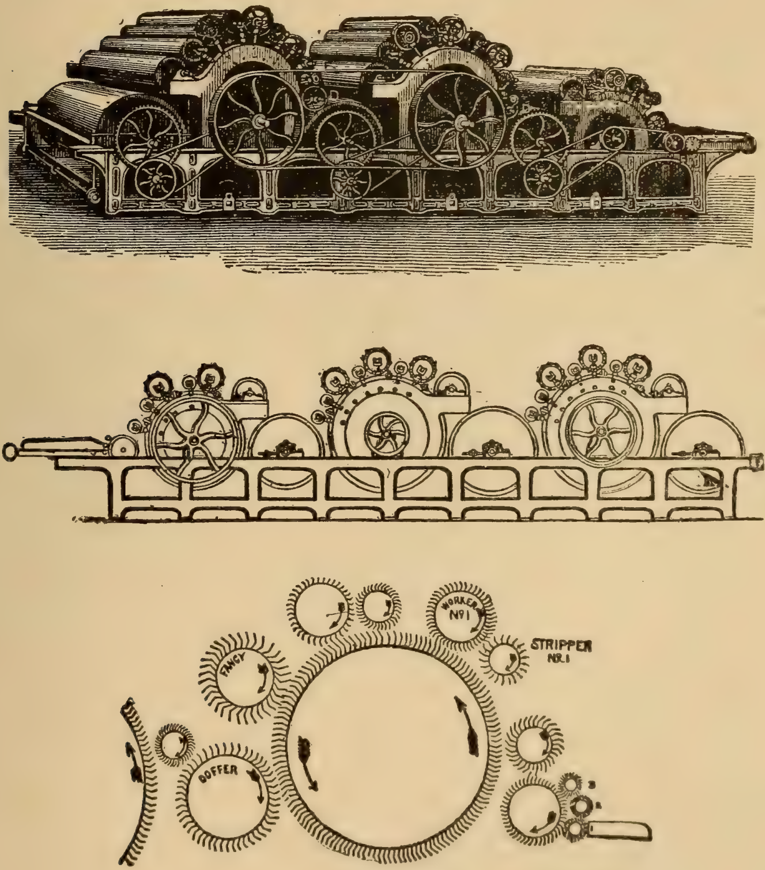
What is the Wool Scribbler?

The scribbler or scribbling card, with its similar engines, is a

DOMESTIC DYEING.

MAKING INDIGO PHILIPPINE ISLANDS. (PAGE 407)

complex series of delicate and expensive machinery. Around a large cylinder with many teeth, revolve in different directions,



Figs. 152, 153, 154. THE WOOL SCRIBBLER AND DIAGRAMS.

as many as twelve small toothed cylinders. The Wool goes into this machine and is torn in ten thousand ways. Two or three of these engines transform the Wool into a round sliver, that can be handled on the spinning jenny.

Is there much to be done after Woolen Cloth leaves the Loom?

The greater part of the labor remains. As it leaves the loom the cloth is called "roughers." It is full of oil and size, and it must be "fulled" or "milled." Soaking with hot soap-suds,

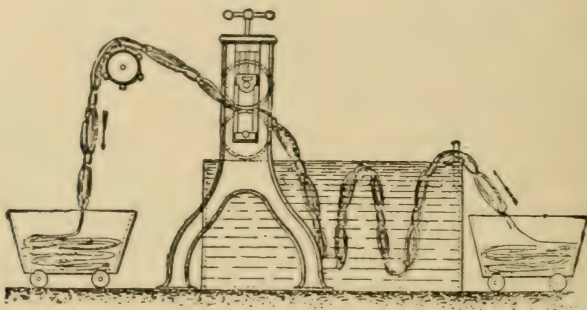


Fig. 156. WOOLEN CLOTH OPEN WIDTH SCOURING MACHINE.

the cloth goes through rollers until it shrinks and felts, sometimes to half its original length and breadth. It is now washed, dried and stretched, and is ready to take the nap.

What are Broadcloth, Doeskins and Meltons?

They are highly milled Woolen Cloths with a nap, and this nap is produced in a way that will interest the student of practical affairs. An herb called the *teasel* bears little hooks on its seed-pod. The manufacturer binds these teasels on a large drum, thus making a card with tiny, weak little hooks. This drum he revolves over the soft Woolen Cloth. The hooks catch the Woolen fibre and draw it out so it will hide the warp and woof. The hook is nearly always weaker than the fibre. The cloth is then pressed, and offers a less shining surface than satin. All substitutes for teasels are given the same name by the weavers. Teasels have been grown by speculators, and the crop is separated into kings, middlings and scrubs. This Cloth has been worn by the English-speaking men as "best clothes" more than any other, but its use grows less general of late years. For state occasions, for dress-coats, for ministers and other professional men, Woolen Cloth with a fine nap continues to be held in the utmost estimation.

What are Woolen "Stuffs"?

They are all sorts of cloth that have not been operated on to make a nap. Rather, they may have been singed, sheared, soaked, scoured and pressed, leaving the texture in plain sight. Of this order are serges, repps, merinos, delaines, tartans, camlets, says, etc. All the plain furniture coverings are of this order. Cropping (shearing) is now done by a machine.

Name some other Woolen goods.

Cassimeres are the chief materials of men's business wear. *Cassimere* was once *Kerseymere.* It is a twilled cloth, where the *woof* passes over one and under two *warps,* the pattern changing each time so as to make diagonal lines. This cloth is more flexible than plain cloth of the same material, hence its popularity. Flannels and blankets are loosely woven cloths from yarn that is itself loosely spun. Such cloths are not milled, nor must the housewife subject them to milling or felting processes by washing them in hot soap-suds without restretching.

But classify the Woolen Cloths more thoroughly.

First the milled and fulled cloths that are felted, napped and pressed—broadcloths, meltons, doeskins, beavers and friezes. Second, the cloths that are milled and cropped bare, with no desire to felt them—these are the great body of men's wearing apparel—tweeds, diagonals, silk mixtures, men's worsted. Third, the "stuffs." Fourth, the hosiery knittings. Fifth, the carpets. Sixth, the blankets, flannels, shawls, etc. Seventh, mixtures with hair and "grasses," etc.

What is the peculiarity of Worsted?

In worsted cloth the Wool is carded or scribbled from a long staple or hair. These hairs are laid in paralled lines. They are then twisted very hard into yarn and woven into cloth in a *twill* pattern. The chance to *felt* is very small. This cloth resists wear, but has the disadvantage of so throwing the light as to give the appearance of being outworn long before the texture is really harmed by service. When the inventors secure a worsted cloth that will not shine in streaks, the ideal wearing cloth will have been attained.

What are the essentials of Carpet-Weaving?

The starching of the threads and the looping and printing or dyeing of the upper warp. Through the introduction of a substitution of the textile grasses and shoddy, the price of carpets for offices and households has been rapidly cheapened. Within the last twenty years the best fabrics of this order have been within the reach of all households. The oriental rugs have also been imitated and hawked from door to door. The Turks themselves have established magazines for the sale of their beautifully-dyed, soft long-wearing Wools, and the people have all shared the benefits of the progress in this line of the arts and its commerce.

What was our old-time Ingrain Carpet?

It was the Kidderminster or Scotch Carpet. It was made of two and later of three webs laced togther. This Carpet can be woven with the Jacquard cards. It is liked by many housewives because it can be turned, mended, etc., and is a yard wide. But its use is not economical. The warp is worsted-spun ; the woof is a softer twist.

What was Brussels Carpet?

A much heavier web, only twenty-seven inches wide, with a linen under-warp and woof, supporting rows of worsted loops. Vast numbers of hanging bobbins were used for the worsted warp, and the Jacquard cards operated on these threads, as in a lace machine. The loops were made over a round wire, and left uncut.

What was Moquette or Wilton Carpet?

The same fabric, with the worsted or softer Woolen warp loops cut after the wire was drawn out, or by drawing the sharp wire out.

How did the Tapestry Carpets change all this?

Whytock invented a process of *printing the yarn* for the loops, so that *after* it was woven it would make a figure in the loops of the carpet. Threads miles in length were colored by steps of half an inch or less. The upper warp was now put on the beam as of yore, and the Jacquard cards (at $350 a pattern) were

no longer needed. In this way, tapestry Brussells Carpet came to be sold three times as cheaply as before. Of course, the loops could be cut to make the velvet Carpets of different names.

What is the patent Axminster Carpet?

This is the modern velvet Carpet, with unstarched, Turkish-like pile, that has entered our best rooms, to the exclusion of even the handsomest Brussells carpets. It was invented by Templeton, of Glasgow, and we will attempt, at least, to give the main principles of the process. It is, briefly, to hasten the methods of the Turk. A web of double chenille (soft Wool yarn) is first woven; this is cut into strips, and these strips then become fringes, to be set upright in the second web that is now woven. The carpet itself becomes a soft brush. The figure is composed by using pile or wisps of the brush or velvet that have different colors.

How is the Axminster pattern secured?

On paper, and in the exact colors to be followed by the chenille-weaver, the design of the carpet is painted. This paper design is ruled off into tiny squares, for exact measurement, and cut into longitudinal strips, which guide the chenille-weaver in the use of his yarns. By means of this guide, when the chenille web is cut into pieces, in order to prepare it to become the cross-thread or "cross-brush" in the upper part of the second weaving, the ends of the upward-sticking brush of chenille yarns form the flower or figure. In fact, the old velvet Carpet loops are turned over or reversed; they are put closer together; they are not starched. Finally, the Turkey-carpet weaver is rapidly imitated, and his carpet is acknowledged to be the best.

What influences on the health have affected the Carpet-trade.

It is seen that the velvet Carpet, particularly, should not be fastened to the floor, or in the corners of the room, owing to its capacity for dust, and the facility with which it sets dust free into the air. Hard floors, with rugs that can be easily shaken are accordingly taking the place of carpeted rooms, notwithstanding the sense of bareness, and the almost dangerous

smoothness, of such surfaces. The advance in the knowledge of microbes has given an impetus to this hygienic movement.

How is Felt manufactured?

Laps or plaits of carded Wool, from the scribbling engines are laid on top of one another. The laps are very thin, and the upper and lower ones are usually of Wool or fur that is finer or more rare than the inner laps. The compound lap now passes between rollers, the upper roller solid and heavy, the lower one hollow and steam-heated. Water is supplied by partial immersion. The upper roller oscillates to aid the felting. It is probable that ancient man washed the oil out of Wool with alkaline earths or ashes and then trod the Wool on a hard place till it felted. The Wool weaver oils his yarns to keep them from felting while he weaves. There is a wide modern use of Felt—for horse-blankets, carriage robes, printed carpets, boiler-covers, piano-covers, table-covers, etc. Broadcloth, etc., is largely felted after weaving.

How are our round Felt Hats made?

The Felt may be a mixture of wool, beaver, otter, rabbit and other hairs or furs. The Wool is manipulated on a rapidly-revolving hollow metallic cone. This cone has holes in its sides, and within it, a draught of air is sucked in by an exhaust-fan. Thus the Wool is sucked on and held to the cylinder. In this way a comparatively enormous hat is made. It is then bathed in sulphuric acid and otherwise shrunken in size. This is the "hat-body." It then goes to the dye-house. It is stiffened with shellac and alcohol. Hat bodies are made in the East and shipped to hat-finishers in the West. The finisher puts the felt cone on a wooden block, steams it constantly, varnishes it, irons it, scrubs it, wires the brim, binds it and puts the band on. The result is a head-covering which is worn by nearly all classes. For the soft hat there is no stiffening and far less molding in steam.

How is this steam applied to the Hat?

The hat-finisher has a "steam-forge." In the middle of his table is a grating from which rises a geyser of steam. This steam is caught in a great funnel overhead. The hat on its

mold must be often held in the steam. This makes the work-room a hot, damp and disagreeable place. It is said that a hat-finisher can be known by the peculiar callosities which the block makes on the back of his left hand.

What other interesting thing is to be said of Felt?

A vast number of yellow people, inhabiting Central Asia, keep their women busy making Felt.

How is Plush for Silk Hats made?

It is woven with an upper warp-beam of very soft reeled Silk. This upper warp is looped up far higher than is usual for the velvet style of weaving, and the loop has no sizing or stiffening. The under warp and the woof threads may be of inferior Silk or of Cotton. When the loops are cut they are dressed all in one direction, pressed and made ready for market. Lyons is the centre of this manufacture. The tall Silk hat continues to be the head-covering for Europeans and Americans on state occasions, and is also worn by professional men. Silk plush displaced beaver plush and fur.

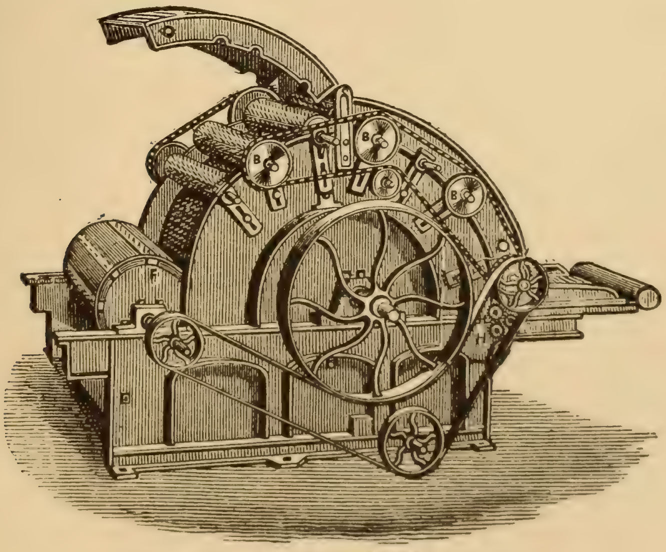


Fig. 157. MIXING WILLEY FOR SHODDY.

What is Shoddy?

Shoddy is the restoration of Woolen rags and cloth to a fibrous form, and a re-weaving of the goods into new cloth. Or the shoddy lap may be mixed with new slivers or rovings for the weighting of new goods. It is a business of rag-picking, old-clothes buying, sorting, washing, etc. Cotton is charred out of the mass by the action of sulphuric acid. The shredding cylinder has eleven thousand teeth. When this scribbler is done with a rag, even the yarn that formed the web has been torn into its original parts. More shoddy-fibre is made in the United States than anywhere else. It was first heard of here in the times of the civil war. It is essentially an economy, and makes the cheap Woolen suits of the day possible. It is said, with what truth we know not, that 2,500,000 persons in the United States are connected with the manufacture of shoddy-fibre, shoddy cloth and shoddy garments.

What astonishing difference remains between the manufacture of Clothes for Men and Women?

Clothes for men are kept ready-made, and tailors also thrive as a class, while the outer garments of women are still made at home, without the advantages to be derived from steam-power and a division of labor. The fashions of women's dresses undergo constant change, while men usually wear out their clothing. The supply of ready-made Cotton goods for women, however, has made great progress.

What is Linen?

Cloth made from the fibres of Flax. This shining white cloth is used for the table, for the fronts of shirts, for collars, and for cuffs. Cotton sheets have supplanted the use of Linen in our bedding. The spinning and weaving of Linen yarn was one of the earliest of man's arts. Linen was long needed as the warp of all goods that carried a Cotton woof, as the Cotton yarn could not be spun strong enough. Of late years, Cotton has come to serve in nearly all the places of Linen, and even in goods sold as pure Linen, inner surfaces of Cotton are imposed on the buyer.

STRIPPING MANILA FIBRE FROM THE TREES IN THE PHILIPPINES.

DRYING AND TWISTING MANILA FIBRE IN THE PHILIPPINES.

Fig. 158. *A*, FLAX PLANT; *B*, FLOWER; *C*, FRUIT.

What did the Nineteenth Century bring about?

The Linen industry was driven to the wall by Cotton, and it flourishes (or languishes) now only in Russia, Ireland and Central Europe, where the modern mill and its agents have not yet conquered. Linen has become a luxury, like Silk in China. Thus, in two parts of the earth, it has been found that the people could clothe themselves satisfactorily at far smaller expense.

How is Flax prepared?

It is pulled out of the ground. Its seeds are especially valuable as furnishing an oil which is the best vehicle in which to carry white lead for paint, but here, also, Cotton seed oil has come forward to take the place of linseed oil. The Flax is immersed in ponds, and retted (rotted); it is spread in the meadows to bleach; it is beaten; it is scutched or split; it is heckled (carded); it is spun into yarn; it is bleached as white as snow in the sun, or by acids: it is woven. The same spinning wheel

Fig. 159. FLAX SPINNERS AT HOME.

can be used for Flax and for Wool, but the Irish housewife or maiden would rather spin Wool than Flax.

Why is Linen stronger than Cotton?

The Cotton fibre is a minute tube of cellulose. The Linen fibre is a solid, containing the earthy elements like silicon and magnesium. The Linen fibre is long; the Cotton fibre is short. The Linen fibre is wood; the Cotton fibre is a pure carbon compound.

How is Oil-Cloth made?

A piece of Oil-Cloth twenty-four feet wide has originally come off a loom that had a warp-beam that wide. The Cloth woven was made of Hemp and Flax yarns, and the shuttle was thrown across by a man on each side. A hundred yards of this canvas, rolled up in one piece, might weigh 600 pounds.

What comes of this bale of Canvas?

It goes to the manufactory. Here it is cut in pieces from sixty to one hundred feet long—for we are describing the making of a large piece, for the floor of a lecture-room or public hall. The pieces are taken to the frame-room. Here upright frames stand together, like shelves in a great library, and before each frame is a series of four platforms or scaffoldings, connected by stairs or ladders. On the frame, the canvas can be stretched by screws exactly as if it were to become an ordinary oil painting. The back of the canvas is washed with size and rubbed with pumice-stone. When this is dry, a layer of thick paint is spread with a long steel trowel on the back of the canvas. Ten days later a second layer of trowel color is laid on. This completes what will be the under side of your Oil-Cloth.

What is done on the other side of the Canvas?

The size goes on, the pumice-stone is used, the trowel color is laid on; it is then rubbed with pumice-stone, and two more layers and rubbings follow. Now a fourth coat of paint is applied with brush, and this is the background of your Oil-Cloth. Two or three months have now elapsed.

How is the Oil-Cloth printed?

With wooden blocks, by hand, as was the case with Calico in

the old days. The Oil-Cloth passes over a large table. The printer inks his blocks as you do your rubber stamps—on cushions. The printer strikes the block a blow with a mallet, as a printer takes a hurried proof of type. The block is about eighteen inches square. A second printer follows with a different color and block, and a third, until the pattern is complete.

Why does not the Oil-Cloth break?

Primarily, because the size has protected the inner cloth-fibres from the earthen matters of the paint. The oil also acts on the earths, to render them somewhat pliable.

What are our household uses of Oil-Cloth?

We put it under the zinc on which our stove stands, to increase our security against fire. We put Oil-Cloth in the vestibules of our houses, where snow melts, in bath-rooms, where water may reach the floor, in strips on stairways, at water-sinks and around kitchen ranges. Very handsome small stove-patterns are now common and cheap, as machinery can be used in their fabrication. The Oil-Cloth interest in America reaches many millions of dollars. The foreign Oil-Cloths emit a far more disagreeable odor than our own manufacture.

How long has Oil-Cloth been made?

In the London *Mercurius Politicus*, No. 606 (February, 1660), is the following advertisement: "Upon Ludgate Hill, at the Sun and Rainbow, dwelleth one Richard Bailey, who maketh Oyl-Cloth the German way; and is also very skillful in the art of Oyling of Linen Cloth, or Taffeta of Wooling of either; so as to make it impenetrable, that no wet or weather can enter."

What is Linoleum?

A floor-cloth, invented by Walton, of England, by which ground cork and linseed oil are applied to jute canvas. Linseed oil is oxidized or aired and thickened until it can be cast into bricks; cork is ground; the two substances are pressed upon or into Jute Cloth between rollers that are steam-heated. This cloth has the advantage of being more soft or noiseless than Oil-Cloth.

What is Lincrusta-Walton?

It is Linoleum, on the top of which molded Linoleum material in various colors has been superposed or embossed. Thus colored, tile-like patterns can be cast and affixed to the substratum, or any raised and bronze-like arabesquerie can be managed. The richest wall decorations of recent times have thus been secured. A story is told of a New York candy-seller who decorated his store with the costliest embossed patterns of Lincrusta-Walton, at an expense of many thousand dollars. The store became a "lion" on Broadway, and the landlord, hopeful of gain, rented the place to a rival candy seller who would pay twice the rent. What was his chagrin, however, on entering the store the next time, to find it tastefully decorated with wall paper that had cost only ten cents a roll!

Is Straw woven?

Yes. The manufacture of hats for men, and formerly of bonnets for women, has given to this industry a leading place in commerce. In all countries, the men don straw hats in the summer. The fields of Tuscany long produced the best straw that could be found for bonnets—hence the once famous Leghorn hat, made of wheaten stems. The true Panama hat is made from the leaves of the screw pine. Massachusetts long had the straw hat trade of America. In the old days, the straw hat was always soft and pliable. It is now nearly always very stiff with starch or sizing.

What are the "Textile Grasses?"

Beside flax, the very important ones (so-called) are hemp, jute, manilla, sisal grass, Tampico fibre, flag and coir yarn from the husk of the cocoa-nut.

What great manufactures arise out of these materials?

Our Oil-Cloths, mats, coarse twines, clothes-lines and sail rope, matting for summer carpets, chair-bottomings, grain bags and covering for cotton bales. As there are sometimes ten million bales of cotton, this alone makes an enormous industry. Accordingly, as fine Linen fabrics have become rare, coarse hemp and jute webs have increased, until now the looms and

spindles of these factories are counted with pride by the census-takers. The bagging and baling of a vast country like the

Fig. 160. THE JUTE PLANT.

United States promise to increase. Our coffee and chocolate also comes to us in bags. The bottoms of all our fine carpets are nearly always of hemp or jute.

Where does our binder twine come from?

Much of it from the Philippine Islands. The "manila fiber" is taken from a plant or tree (see illustrations) which is a species of the banana family. In the Philippine Agricultural Building at the World's Fair at St. Louis, there was a fine display of shrub cotton, tree cotton, all grades of hemp and every variety of fiber and flag found in the Islands. The natives are expert weavers and make many articles of utility from the textile grasses. The flag is in great demand. The houses of the poorer classes are thatched with flag. On more pretentious buildings, the roof is woven. The flag is also used for weaving mats of all kinds and for cart covers and other articles.

Tell me about Indigo.

The word is the Spanish form of the Latin word for *Indian*, as the Romans received the dye from India. Marco Polo (A. D. 1295) describes the very process shown in our illustration. He says the natives press out the juice, which dries into a mass. It is then cut into the pieces which reach the market. The plant is soaked with the roots on. The Japanese have great establishments at Tokushima. In the picture, "Domestic Dyeing," we give a scene that once was frequent in America.

What is to be said finally of the Textile Arts?

The wide expanse of the Cotton States was given to the cultivation of the Cotton fibre. The cards were placed on a cylinder. The spindle was set on end and flying arms given to its point. Stretching rollers were added, each doing the work of many hands. Steam power was used to propel the loom. The Jacquard cards were attached to lift and depress the warp. Two or more warp beams were used. Revolving shuttle-boxes supplied different shuttles. The various lace machines were made, weaving many kinds of mesh. The felting, napping and shearing of thick cloths began. The use of the textile grasses for the underside of carpets was found to be prudent. The methods of the Turk were put into mechanical operation for velvet carpets. The secrets of chemistry were exposed, and the hydro-carbon colors triumphed over all. Cloth was printed as if it were paper, and as rapidly. Until at the present day the infinite fancy of man for different forms has been pleased, and no single catalogue contains the names of all the products of the loom.

India Rubber.

What is India Rubber?

As we know it, India Rubber is a tree-gum or milk, mixed with sulphur and pigments, molded and steamed or dry-heated in a tight chest or vulcanizer. A quarter of sulphur, three-quarters of gum and 270 degrees of heat make a soft, elastic substance. A half each of sulphur and gum with 370 degrees of heat continued six times longer, make ebonite or gutta percha. Many minor chemicals are added by various manufacturers. The process was called "vulcanization" by Goodyear.

What is the gum called India Rubber?

A remarkable union of atoms of carbon and hydrogen alone, by which a unique compound is obtained. This compound is the most elastic of substances and at the same time among the most impervious to air and water. But it was for centuries so sticky and unstable, that it could not be used for clothing, etc. The life of Charles Goodyear, an American, was devoted to the experiments which resulted in the every-day use of India Rubber and Gutta Percha by the people.

What is Gutta Percha?

Gutta is the Malay word for *gum*, and *percha* is the tree the gum comes from. But there are many trees that yield the milky gum that we make into India Rubber, and we use the word Gutta Percha to mean India Rubber that has been vulcanized until it is perfectly hard, and capable of carrying a high finish.

GATHERING RUBBER MILK. (See page 408.)

MAKING RAW RUBBER. (See page 410.)

WEAVING ROOFS—PHILIPPINE ISLANDS. (Page 406)

Fig. 161. THE INDIA RUBBER PLANT.

How do we find ourselves indebted to the use of India Rubber?

When we telephone, we use gutta percha. When it rains or is muddy, we encase our shoes in rubbers or overshoes, or hunting-boots. At our desks we are in constant need of a rubber eraser (from which need, indeed, the rubber takes its name), and rubber bands are daily coming into more general use for the wrapping of articles that are not to remain long in their wrappers. There is rubber in nearly every pair of suspenders, whether for child or man. The garden hose is of rubber. Wrapped around the bicycle wheel that hose becomes a rubber tire, while the horseman and the horseless wagons are both inclined to accept the rubber tire as a part of their future. Our water-bottles, syringes, door-listings, mats, piano-covers, wet-weather coats, gossamers, knife-handles and combs are often of rubber or gutta percha. Rubber stamps do a great deal of printing, especially of dates.

What natural objections to manufactured India Rubber arise?

Its sulphurous odor offends the sense of smell, nor does this

fault disappear from Gutta Percha itself. Its capability of excluding water and air carries with it the incapability of letting air or water out, so that the feet are never wholly comfortable while encased in rubbers. It is noticed that heavy arctic overshoes, if covered on top with cloth that will allow the passage of air and the absorption of moisture from within, will heat the feet less, or will keep them dryer than thin rubbers that entirely cover the shoe. Foreign chemical treatment of rubber is even less successful than our own. Several sections of the German Imperial Exhibit in the Manufactures' Building at the World's Fair were carpeted with a rubber cloth that was offensively odorous, and remained so all summer. Within thirty years the flexibility of rubber under cold has been increased. The *ponchos* of the Union soldier, in 1861, were of rubber. These would freeze stiff on a wintry day.

What is Caoutchouc?

It is the South American word for India Rubber. It is pronounced *Koo*-chook. But American ears have refused to receive it as a common word. Rubber is yielded by trees that grow in a belt five hundred miles wide on each side of the equator, all round the globe. The best comes from Para and Ceara in South America; the next best from Mozambique and Madagascar. It is grown in West Africa, Malaysia, the West Indies, Central America and Australia. We import in the neighborhood of twenty million dollars' worth of unmanufactured rubber each year. When pure, rubber is odorless, nearly white, and nearly as heavy as water.

In what form does Rubber reach America?

The people at Para burn oily palm nuts in a bottle or vase. Then dipping a certain instrument, say a stick with a clay mold on it, into the milk, they dry the layer of milk in the white smoke of the palm nuts as it rises out of the vase. Then another layer is dipped, and so on. About five pounds can be prepared in an hour. The "biscuit" is then cut away from the mold, or griddle, or stick, and sent to New York or Boston, where it commands the highest price that is paid. In other places, the natives let the milk dry on the tree, pull the gum off in strings,

or roll it in balls. Some natives prepare thin sheets or disks of the rubber, not two feet in diameter. It also comes in "negrohead," "knuckles," "thimbles," "tongue," "cake," "liver," "junk," and other sailor and trade names. The best Madagascar is pink in color.

How are these pieces of Rubber manufactured into the articles we use?

They are not melted over a fire and molded, as we might suppose. Where molding is necessary, solvents are used. After soaking in hot water, the pieces are cut into slices by hand, and then washed between wet grooved rollers. Solid impurities are crushed and washed away. As the rubber pieces stick together when they touch, the rollers send out finally an irregular porous sheet, which is hung up to dry or dried in trays.

What is the Rubber Masticator?

It is an apparatus consisting of an outer iron cylinder; inside a roller with corrugated surface revolves. The roller may be tilted irregularly in the cylinder. The rubber goes into the ring-like hole that is open and gets kneaded into a mass that can be pressed into solid blocks or bricks.

What is done with the blocks of Rubber?

They are fed to a wet knife that makes two thousand cuts a minute, and thus the blocks are sliced into sheets.

What is Vulcanization?

To vulcanize rubber, it must be chemically incorporated with sulphur—each molecule of rubber must have admitted an atom of sulphur. The sheet of rubber can be dipped into melted sulphur, and then submitted to the action of high-pressure steam.

Cannot Sulphur be mixed with the washed Rubber?

Yes. Sulphur to one-tenth of the weight of the rubber may be added, together with any one of such pigments as vermilion, oxide of chromium, ultramarine, antimony, lampblack, arsenic, or oxide of zinc, and even whiting and barium sulphate may be added. After this mixture is masticated, it molds more readily, or can be rolled into the sheets that are needed for clothes and

for elastic bands, for desk or loom. If the mass is to be made hard, various substances may be added. With tar and with magnesia, gutta percha may be made.

How is Rubber Hose made?

It can be forced through annular holes, like lead pipe or macaroni. Or textile hose can be saturated with a solution of rubber.

How is Rubber made solvent or liquid for the time being?

With chloroform, ethers, alcohols, coal products and carbon-sulphur compounds. Rubber can be thus dissolved until it will filter through paper, and when dried, leave films of exquisite tenuity. A treatise on the ordinary commercial rubber compounds would be an extended treatise on chemistry, as many of the Elements are used, and in many ways.

How is a Rubber Ball made?

Mixed rubber is softened by heat, when it becomes like clay. A hinged metal mold of a ball, tinned inside and greased, is opened and its surface is covered with a layer of rubber, kneaded in. A little carbonate of ammonia is inclosed in the mold as it is shut, and the mold, is without any core. The mold is now put in dry steam at a high temperature for an hour. The air and the carbonate exert great pressure on the inside of the rubber, forcing its outer surface against the face of the mold and making it smooth. The two hemispheres of rubber are also welded together, and nearly all rubber toys show the seam left where the mold came together. The operation is not unlike the molding of a lamp-chimney by a glass-blower—air acts as a core to the mold.

How are Rubber threads woven in suspenders and braid?

The block of rubber may be vulcanized in "spread sheets." The sheets may be cut into fine threads—many thousand yards to the pound. These threads are always stretched on the loom until they have little elasticity left. After the weaving, a hot iron is pressed on the cloth, when the rubber resumes its elasticity and springs back, wrinkling the web, or pressing its woof more closely together.

What has science accomplished with Rubber, of late?

It is found that fine woolen and silken fabrics may be treated with mixtures of rubber, the gum being entirely hidden from view, with no embarrassing weight added to the garment. In this way, overcoats and women's cloaks are made that are not to be discovered as rain-shedding vesture. But it is also true that several of the woolen webs, such as Irish frieze, felt together so firmly that rain will not go through them. These woolens are, however, much thicker than the rubber cloths. If two thin pieces of cloth are painted with a solution of rubber, their surfaces can be easily fastened together by a touch of sulphur chemicals and passage through hot rollers.

How are Arctic Overshoes made?

The cloth overshoe, with its woolen lining, is first made. A mixture of low quality rubber with heavy pigments, always black, is now carefully spread on the lower parts of the shoe that are to be covered with rubber. After the building-up on the sole is deemed sufficiently thick, the last is fastened into the mold which is to give the grating and form to the sole, and the mold is put into a dry oven. The East has this trade.

How are "spread sheets" for Yarn and Gossamers made?

A sheet of cloth is coated with paste, glue and molasses. On this a solution of sulphuretted rubber is spread. If a double layer be needed, two cloths are spread and then joined. Now the cloth is vulcanized by steam heat. The hot vapor softens the paste, glue and molasses, and the cloth can be peeled away. This sheet can be cut into square thread, or used for waterproofs, etc.

How is my Black Comb made?

This, and all the electrical gutta percha articles are the products of over-vulcanization with a high ratio of sulphur. Tar also gives a black and ebonite effect. The rubber is usually kneaded with the sulphur, softened with fluids so it can be molded, and then kept in the vulcanizer from six to eight hours. Gutta percha vessels are useful to the chemist.

How is the red Rubber cast for False Teeth made?

It is gutta percha, highly colored by cochineal. The dentists of the United States carried on an extended litigation with the Goodyear interests over the right to vulcanize their own work in their own laboratories.

What remarkable biographical narrative is connected with the history of India Rubber in America?

The story of the life and trials of Charles Goodyear, who died in 1860. He was described, in the midst of his unhappiness, as follows. "If you see a man with an India-Rubber coat on, India-Rubber shoes, an India-Rubber cap and in his pocket an India-Rubber purse, with not a cent in it, that is Goodyear." All his early rubbers, if made in winter, would melt in summer, with the most abhorrent odor, rendering burial necessary. If made in summer, they would freeze in winter. A hired man named Hayward discovered that ordinary sulphur was the proper chemical agent, and Goodyear discovered the action of heat by dropping some of his sulphuretted rubber on a hot stove. "Try to sleep!" his wife said to him. "Sleep!" he cried, "how can I sleep, while twenty human beings are drowning every hour, and I am the man that can save them?"

How do we get the word Mackintosh?

In 1842, Goodyear sent specimens of his work to Charles Mackintosh & Co., of England, and opened negotiations. One of the partners of this firm, named Hancock, patented, in England, in 1844, a process of vulcanization, but five weeks after Goodyear's patent had been publicly described, according to the laws of France. Both the English and French courts decided against Goodyear's claims, and he died insolvent. Two years before his death, the United States Commissioner of Patents thus spoke of the losses of Goodyear: "No inventor, probably, has ever been so harassed, so trampled upon, so plundered by that sordid and licentious class of infringers known in the parlance of the world, with no exaggeration of phrase, as 'pirates.' Their spoliation of his rights has unquestionably amounted to millions."

Why did Goodyear say "Vulcanize?"

Vulcan was the god of fire in mythology. *Volcano* is the same word, and volcanos are noted for their sulphurous outpourings. Vulcan was at his sulphurous forge under the earth, when the volcano was in a state of eruption. Few modern commercial verbs have been chosen with as much scholarly skill.

What is Carr's Invention?

William Krelfall Carr, of England, the inventor of Cereal Rubber, discovered that macerated wheat, mixed with ptyalin, a chemical compound found in saliva, produces a real Rubber. It was discovered that swine secrete large quantities of the ptyalin which ferments the wheat, and forms a dextrose (see Sugar), which in turn afterward becomes Rubber. Mr. Carr makes six grades—namely, for water-proofing, tubes, tires, matting, paving and for golf balls. It is thought that the world needs, or will soon need, 100,000 tons of Rubber each year. But for new inventions of Rubber, the price would soon become prohibitory. Recent chemical and commercial developments on this line of artificial Rubber have become extremely important, and millions of dollars of capital have been interested. The work began in Essex, with the Coats' (Coats' thread) group of capitalists at the head.

Needles and Pins.

How are Needles made?

From fine steel wire, by a long and painstaking process, involving much machinery and tasking the health of the workmen. The fine wire is coiled. The coil is itself cut into double Needle lengths. Bundles of these short wires are heated, and rolled and pressed until they become straight. The wires now go to the grinder, who with apparatus, is able to hold a great many Needles against a dry grindstone, while, with his right hand, he slowly revolves the Needles as they are pointed. He is thus able to make 100,000 points a day. A hood covers the grindstone and an air-suction attracts some of the dust that fills the air around the grinder. Where a grinding-machine is used, the Needles are bound by a rubber band on a wheel, sticking out a little as they lie flat across the tire of the wheel. The wheel revolves so that the Needles touch a curved grindstone revolving in another direction, and the Needles are pointed more rapidly.

How is the Needle-eye put in?

The double-pointed wire is now ground flat at its centre (it is still a wire for two Needles) and stamped with the grooves and eye-places. The eye-holes are next punched in. A delicate wire is run through the eyes of a hundred or so of the wires, and the whole comb of wires fastened up tightly with clamps on each side, so that the eye-holes and grooves can be smoothed out. Now the clamps are broken apart, the wires breaking readily at

their centres. With the clamp still on, the hundred Needle-heads of one side are rounded with files and wheels. The wire is withdrawn and the Needles are handled separately, if need be. They are then tempered by heating in a muffled oven and plunged in oil, then reheated, and then gradually cooled.

How does the Needle get its high polish?

Bundles, each of several thousand Needles, in a mixture of soap, oil and emery powder, are bound tightly with canvas. They are then put in the bed of a machine which keeps them rolling over, with some friction, so that the Needles must rub among themselves. After this, they are washed in soap and dried in sawdust. Next the mass of Needles is emptied on jerking trays that gradually get them all parallel to each other, but some of the points are lying one way and some another. A man with a "finger-stool" now presses this piece of cloth or cushion against a row of ends, and all that are sharp stick in. He is called a header. Those points that miss are faulty, and are thrown out. If the eye-holes are to be blued, this is done by binding the Needles on a wheel with a rubber band, and running the projecting eyes through a gas-flame. To smooth the inside of the eye-hole, so that it will not afterward break its thread, a wire is daubed with emery and oil, and the Needles are strung on the wire. Rows of Needles thus hanging are kept dancing in frames until they well smoothed inside. The Needles are finished by careful manipulation on small grindstones and buff wheels with putty powder. In late American manufactures the groove is omitted, the bluing is not done, and the head is ground very close to the eye-hole. The seamstresses prefer these Needles for fine work. They are also cheaper. The practice of gilding the heads did not gain much headway in this country.

Is the Needle an ancient instrument?

Yes. It ranks next to the stone ax and grinding bowl. It was made of fish bone. But doubtless thorns were used as early as fish-bones. Steel Needles were first made at Nuremberg, Germany, at the end of the fourteenth century.

What remarkable thing did Elias Howe do?

He put the eye of the Needle at the point, and thus invented the sewing machine, uniting the Needle and the loom in the operation of sewing. It is said of the sewing machine, however, that it has created unnecessary stitches to as great a number as it has saved necessary stitches by hand. Through the spectacle of adornment by stitches, we are perhaps led to the conclusion that work, in itself, if voluntarily pursued, is one of the chief pleasures of man. But to make unnecessary labor a painful means of livelihood, is something that governments may eventually prevent.

Did all Sewing-Machines have the Loom principle?

No. By some of them the thread, as it went below, was caught by a hook, which made a loop, or knitting. These machines, though using a third more thread, were the swiftest. They also unraveled easily. In other very swift machines the bobbin was a thin revolving disk, which did not shoot back and forth. But in the best-known makes—that is, the ones that require the least mechanical knowledge to keep them in good order, the shuttle shoots back and forth through the loop of thread, exactly as if it were in a "shed" in a loom. There is a likeness between the variation which put the point in the eye of the Needle, and that invention of Arkwright which put the flyer on the point of the spindle.

How are Pins made?

Two parts of copper and one part of zinc are melted together and cast into a long ingot. This is rolled into sheets. The sheets are cut into strips. The strips are drawn through holes in steel plates. The wire thus made is annealed and re-drawn. It is hung on a reel over the Pin machine. Rollers draw in the wire, and it is cut into a Pin-blank, headed in a die. Four revolving files put on the point, and an emery belt puts on the first polish. Pins drop from this machine at the rate of one hundred and sixty a minute. The Pins are put in a revolving barrel with sawdust, and scoured. Then they are boiled in Tin, washed with soap, and again tumbled in sawdust.

Where do the Pins go next?

Into the sticking machine. The Pins are put in a hopper, slide lengthwise down an inclined plane in separate gutters, reach a plate that holds a row, and the row is pushed into the paper, whose crimps are ready for the thrust. The paper is fed in from a roll, and is cut after the Pins are stuck. Some papers hold twelve rows, thirty to the row. Cheaper papers go twenty to the row, and fourteen rows to the paper. Formerly, the town people where the Pin factory was established, helped to stick the Pins in creased paper, at their homes, at six cents or so a dozen papers. Machine-made Pins are an American invention, and Dr. John T. Howe established the industry in this country.

How are Mourning Pins made?

From iron wire, and japanned—that is, painted and annealed. They have been variously headed, often with wax, then with wire spirals, and finally in the same way a tin Pin is headed.

It seems to me that Safety Pins are increasing in use?

Yes. Probably because of the invention of a machine for their manufacture. They are cut from spring steel wire, sharpened by the revolving files, flat-headed and guarded, spiraled at the center, and made ready for the tin bath before they drop from the machine. These Pins are found by mothers to be more satisfactory than buttons for the underwear and night dresses of their children, and for use in holding skirts together.

What becomes of our Pins?

This oft-asked question is to be answered in the following manner: The modern Pin is cheaply made and often poorly tinned. Its point is often defective and always of short life, if used. The women become expert as judges of good Pins, and with the little instruments so cheap, there is no need of economy in saving either a rusty or a pointless Pin. Thus many Pins are thrown away. The week's sweeping always reveals a number in the dust that is accumulated, and these are not always in good condition. The children deal in Pins as their first real currency, before they deal in marbles, and the wear on Pins so used takes nearly all of them out of any other use. If ten Pins were lost

each week in twelve million homes, the consumption each year would be over six billions. But, beside the children, there has come to be an enormous use of Pins in the counting-room and at the desk, where documents are pinned together. It is not improbable that the Pins of the large cities go under the pavements, as the street-sweepings find their way to new and unpaved thoroughfares that are below grade.

Glass.

What is Glass?

A hard and brittle substance, through which the light easily passes. Heat, on the other hand, is held back, or obstructed. Thus Glass is melted only at a high temperature. It has a remarkably smooth surface, which will be roughened only by ages of exposure to water, and no acid except the sour compounds of Fluorine eats into it. It thus furnishes us with our Glass windows, our bottles, and our best apparatus for artificial light.

What is Glass, chemically?

Glass is a compound in which there must be three ingredients: 1. A sour compound of either silicon or boron; 2. An oxygen compound of either potassium or sodium (or both). 3. (For transparent Glass.) An oxygen compound of *one* of the following Elements: Calcium, lead, barium, strontium, magnesium, aluminium, zinc, or thallium. (For colored Glass): Iron, manganese, copper, chromium, uranium, cobalt, arsenic, or gold. In brief, Glass is a silicate or borate of at least *two* metals, and one of these metals must be an alkali. The molecule of Glass may be theorized, in the most simple manner, as three oxygen molecules, each one holding a molecule respectively of sodium (or potassium), of calcium, and of silicon (or boron)—that is, soda (or potash), lime and sand (or borax, which also has soda in it). (See Chemistry.) Many other elements are introduced.

What is required for Glass-making?

A very great heat, and as most Glass articles are small, the Glass furnace is often divided into small pots or compartments. Siemens and Stevenson invented tank furnaces, to do away with the little pots, but each plan has its advocates. Usually, a Glass factory—as at the World's Fairs—is a tent-like structure, in which the tall chimney is the centre-pole.

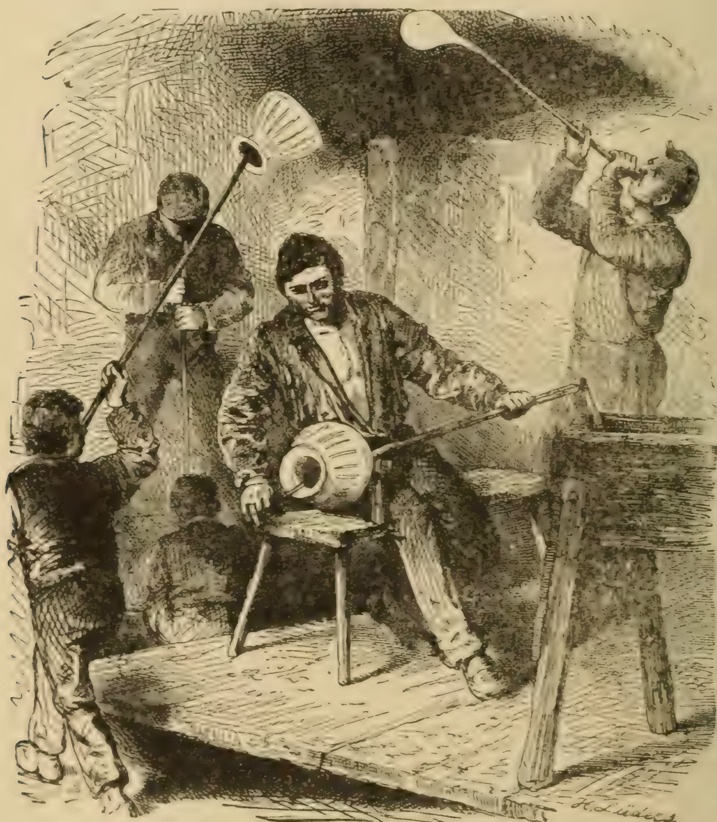


Fig. 162. FASHIONING GLASS SHADES.

How is this Glass bowl made?

A man gathers molten Glass on a rod and holds it over the

mold; the pressman clips off the hot metal with shears; the mass drops into the mold; the mold is shut and pressed and the bowl is taken out, still red hot. It can now be further heated, wrought with a block of wood, and is cooled in a tempering oven.

How are the molds made?

They are of iron, jointed in many places, so that they can be opened without breaking the Glass. When a vase or pitcher is smaller at the top than some part of its interior, it has been wrought with the wooden block; *or*, it has been molded another way.

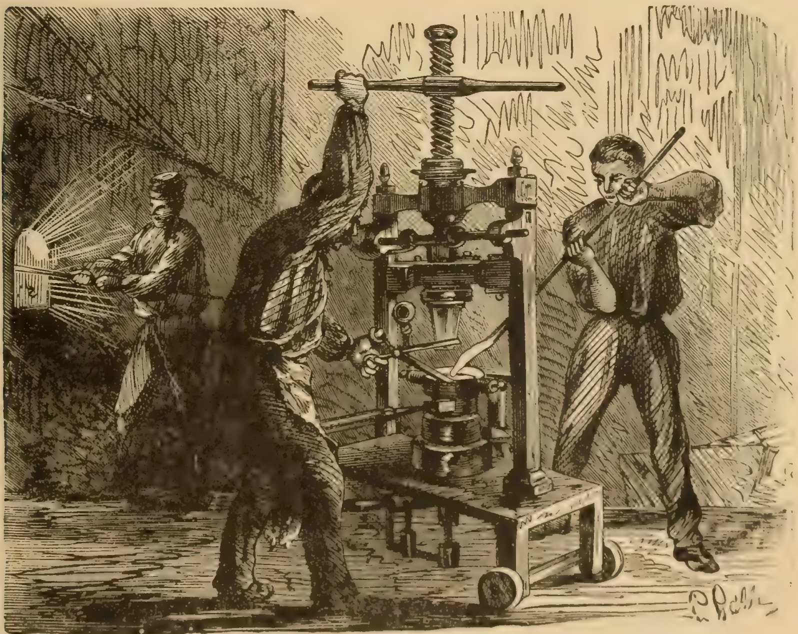


Fig. 163. MOLDING COMMON TUMBLERS.

How can Glass be molded in any other way?

The rod, or Blowing Tube, which gathered the "metal" in the pot, may have been hollow. The blower, a man usually of enormous lung-power, by gathering a pound or so at a time,

and making many dips, may finally have a heavy load on the end of his tube. He may now place this mass in a mold which has no core, and by mere lung-power, blowing into the mass, may force its outer sides into every crevice of the mold.

How are the letters and figures made that we see on goblets, druggists' bottles, etc.

These designs are engraved. with great art, into the sides of the metal molds. As these have been cast, polished and hinged at great expense, the artist must make no mistaken move with his chisel. Complicated designs sometimes require months of labor in the engraver's hands. The cost of the molds for a table set is from $2,000 to $4,000.

What is the "Gluhey"?

It is a hot oven or sub-furnace. Here the rough surface of the Glass, due to contact with the iron mold, is again fused and made brilliant, but at the expense both of the perfect shape of the mold and the delicacy of the engraver's tracery. Hence, the engraving in the mold must be a "working" or practicable design.

What is the Leer?

The tempering oven, a long structure, hotter at one end than at the other. The Glassware goes slowly through, and by this course of cooling is made tough.

What makes Glass milky or untransparent?

Inner crystallization, or crystallization on the surface. Good Glass is as free of crystals as lampblack. But there are crystalline substances, like quartz, that are transparent.

Where does the word "Crystal" come from?

From the Greek word for *ice*. The English people have seemingly attached it to Glass, but Glass is not a crystalline body—it is amorphous—that is, without form.

Why do we say "Flint Glass"?

Flint was once ground to produce the sand, and lead was used instead of lime. Lead Glass is much more tough and

brilliant than lime or window Glass, and is used for lamp chimneys and goblets.

Is there any difference between Soda and Potash Glass?

Yes. Soda Glass is the greener of the two. The green that we see in thick Glass, is probably the green gas, chlorine, that tints the water of the sea.

How is our Window Glass made?

The "metal" is at a great heat in the pots. The gatherer takes his long rod, puts a mask on his face, dips his rod in the metal, takes it out, rolls it over, dips it again, and may gather as much as twenty-five pounds of Glass on the end of the rod. With this he runs to the Blower, a Hercules, who stands over a long, narrow pit. Over the pit, the Blower swings this mass of white-hot metal, which lengthens out into a pear-shape. Then the Blower forces air from his mouth into the interior of the mass, and it begins to form a great bubble. But blowing into it cools it rapidly, and the gatherer must put it into a "glory-hole," where it still retains its bubble-like form, and now tends to stretch out, as the Blower again swings it over the pit. At last, when it has become very large, the Blower is through with it, and must rest to get ready for the next "blow."

How does the Blower get back his rod?

The great bubble or bottle is laid on a wooden horse, and the touch of a cold iron breaks off the rod. The round bottom end of the bubble is cut off by the same means. It is now a very hot Glass cylinder, nearly as flexible as leather. A touch of the cold iron on the cylinder lengthwise splits the glass open.

How is the Window Glass flattened?

The flattening-stone is made of warm fire-clay. A workman with a block of wood for a "flat-iron," opens the cylinder and smoothes it down as if it were a linen fabric. It is now annealed and cut into sheets of the proper size, and it is ready for market.

How are our great Glass windows made?

Very fine sand, lime and potash are used. The "metal" is heated in a great open pot, which is swung away from the fur-

nace on a crane, and *poured* on a smooth metal surface that must be larger than the plate of Glass to be made. The mass is now "ironed" by rolling over it an iron roller fifteen feet long and three feet in diameter. When the Glass is thin enough, it looks milky, and can be used for skylights. For windows, it must be ground or polished.

How is the Plate Glass ground?

On a revolving table. It lies on a bed of plaster of paris, and a grinding engine, using sand, takes off forty per cent. of its thickness. It is finished with emery and rouge. These finishing processes add the notable element of cost that attaches to Plate Glass.

What makes Cut Glass so expensive?

Because a workman has ground every pyramidal point on the outside of the Glass dish, while a boy has kept the wheel wet and supplied emery. The labor of a month may be lost by an accident at the last moment. The process is as simple as the grinding of an ax.

Why is Cut Glass valued so highly?

Because of the extraordinary reflection of light that comes from its pyramids. While Glass has not the refracting power of the diamond, yet by multiplication, the weaker Glass facets combine to give a powerful effect on the eye. But the eye needs some training to observe this effect.

Can Glass be spun?

Yes. It is reeled like silk into skeins and these skeins can be woven into all kinds of fabrics, such as woman's dresses, hat-trimmings, badges, ribbons, etc. Hundreds of these fabrics were exhibited at the World's Fair. For use in show-windows, where dust ruins the ordinary textiles, doubtless Glass goods of this order will assume a certain value. Their danger to the health of the people, through the countless particles of Glass that break off, cannot be overstated.

What makes Bohemian and similar Glass dishes so expensive?

The costly metals, like gold and uranium, are mixed in the melt. The Glass is stretched into wire, and the wire is manipu-

lated into dishes. Where gold is used, the actual metal employed assures a high cost. These delicate and beautiful dishes serve badly for ices or hot water, as, by their fabrication, they can never be adjusted to sudden changes of heat and cold. It follows that the housewife should always wash her own wire-spun Glassware, and use it only for fruits and sauces of the normal temperature of the room. The finest and best wire-spun gold Glass dish is likely to break in two at the touch of ice cream on its surface.

What new thing has been done with Glass?

The iron grating necessary for the protection of Glass skylights in depots and buildings is now cast in the interior of the Glass. By this means, the danger of falling Glass in large pieces is averted; the life of the skylight is lengthened, and the life of the wire netting is made co-existent with that of the Glass. In the absence of such an invention, thousands of dollars of damage was done by hail at the Manufactures' Building of the World's Fair.

How is this Wire Glass made?

The mass of Glass is poured on the table. A steam-heated roller irons it flat. The wire netting is laid on the rolled sheet. A roller with deep corrugations, on the points of which the wire netting would fit, now rolls over the Glass, punching the wire far down into the mass, and leaving it ribbed. A smooth roller now rolls the Glass smooth, so that the wire is buried in the plate. Heat and cold must break this glass, but it is still strong, and of course no large pieces can fall. This Glass is offered to jewelers as a protection for their windows. Great works for the manufacture of this Glass were built at Tacony, Pa., and at St. Louis, Mo. At the former place an eight-pot Siemens regenerative furnace melts ten tons of Glass a day. The architects, however, hope to abandon the use of Glass in skylights, and the inventors are offering wire nettings with amber-like fillings, the leading compound being linseed oil. This is called "Translucent Fabric."

How did the people become familiar with Glass-blowing?

Through the Bohemian Glass-Blowers. For many years

these workmen traveled through America, working before spectators who paid an admission fee. With the aid of a blow-pipe, the great heat needed was obtained, and white and colored glasses were fused together into various shapes, mainly for ornament. The transparency of these vari-colored objects made them look like fruit-juices, and appealed as well to the sense of taste as to that of sight. The objects made up in the beauty of their materials, what they lacked in artistic structure, although they sometimes attained both grace and beauty.

Tell me about the Portland Vase?

It was found in the tomb of the Roman Emperor Alexander Severus, who died, A. D., 235. The vase was made in the following way: A bubble of white glass was formed on the blower's tube; this bubble was dipped in transparent blue, and the twice-dipped tube was again put in the white. Thus, the modeler had a vase whose walls were of three layers. The outer white was now taken off, so that the background of the sculpture was in blue, showing white behind it. The trees and other pictures stood out in white on the blue-white background. The British Museum placed this vase where all could see it, and a drunken man wantonly dashed it in a thousand pieces, and was severely punished for his act. Mr. Doubleday mended the vase with wonderful skill. Wedgewood thought the glass-workers and sculptors of his day could make $50,000 in the time they would be required to give to such a vase. It was about thirteen inches high.

Paper.

What is Paper?

A thin tissue, composed of vegetable fibres, resulting from their deposition on wire-cloth while suspended in water. Paper is very rarely made of animal fibres.

What is its use?

On Paper man records his history, for transmission to future ages. By means of Paper the daily doings of the Old World and New World people are immediately known to one another.

Where does the word Paper come from?

From Papyrus, the inner stalk of the lotus. This plant, now called *Berd*, in Egypt, is more rare there than in America. Papyrus rolls were made in large quantities at Byblos, hence the word *Bible*, for *book*. A treatise many thousand years old, written on papyrus, was found in the tombs of the fifth dynasty of Egypt. The book is now in the National Library at Paris. Archeologists disagree to the extent of two thousand five hundred years as to its probable age, as vast spaces exist in Egyptian history of which there are no monuments remaining.

I have seen the lotus-stalk. I do not understand how Paper could be made from it.

The long reed was slit lengthwise, and several of the peels were flattened out. Muddy water from the Nile or paste was spread on the layers. Then strips were laid transversely on the first layer. Then the mass was put in a press. Then the sheet was beaten with a mallet. Then it was polished with a shell,

and rubbed with oil of cedar. The Romans used this paper as late as the third century, and had many names for the various makes and sizes—including *Emporetica* for wrapping-Paper. Pliny treats the matter in his third book, and Volume Five of the French Academy of Inscriptions contains Caylus' dissertation on the subject.

Where does our style of Paper come from?

From Asia. It was made from cotton, silk and linen. The oldest manuscripts of the dark ages are written on Paper that came from Asia, mainly from Damascus. Beside *charta Damascena*, it was called *charta xylina*, and several other names representing cotton.

What makes our modern newspapers so cheap?

The fabrication of Paper from wood-pulp, a process made necessary or convenient during the scarcity of cotton at the North in our civil war of 1861–5.

Is the wood pulp process a rapid one?

It is. As a test, Mr. Menzel, at his factory, in Elsenthal, Austria (for the process has spread abroad), on the 17th of April, 1896, felled three trees in the presence of a notary at 7:35 o'clock in the morning. These trees were carried to the factory, cut in pieces twelve inches long, decorticated (peeled) and split. The split wood rose on elevators to the five defibrators of the works, where the pieces were ground or rubbed into pulp and the pulp was sent to the vat to be mixed with its chemicals. The pulp then began its journey over the hot rollers of the paper machine, and the first finished sheet appeared at 9:34 o'clock of the same morning. The experimenters, accompanied by the notary, then took a few of the sheets of the Paper to a printing office, two and a half miles away, and at 10 o'clock a copy of the printed paper was in the hands of the party, so that a standing tree was converted into a newspaper in two hours and twenty-five minutes, and it was the belief of Mr. Menzel that he could shorten this interval by twenty minutes.

What wood is used?

The spruce trees of Northern Michigan and similar timber regions furnish the wood, and the logs are cut and boomed down

the rivers after the ordinary lumberman's fashion. The wood-pulp mill has its boom on the river. It may make Paper, or it may make "lap"—a term, as you see, borrowed from the spinners. (See Clothes.) Lap is prepared pulp, ready to be used in Paper mills at a distance.

Describe the process of making Wood Pulp.

The log is sawed into short lengths, and the bark is taken off by a kind of veneering machine. The Michigan grinder does not split the log. It is held against wide grindstones by hydraulic pressure, and water is poured on the stone to prevent fire from friction. The pulp falls from the grindstone through a screen, and a pump forces it through a collender, leaving it a liquid. It is now pumped on the "wet machine." Here it is spread on felt, and the water is nearly all pressed out of it. It is now lap. Layers of these laps are made in bundles and shipped to the Paper mill.

Can Paper be made entirely of this wood Pulp?

No. The grinder has cut the fibre too short, and the pulp is good only for "body." Fibre must be added.

Describe the Sulphite fibre.

Pieces of wood are boiled with sulphur in a "digester." In this way the wood is disintegrated by separating the long fibres, leaving them strong enough for the purpose to which they are destined.

What is "Half-stock?"

Wood pulp and the sulphite above described are mixed together in an oblong tub called the engine. A sizing of resinous soap, starch or alum may be added to give the fibre more value. To make the paper white, either a fine red or blue pigment is to be added, usually a blue. It is now ready for the tank that is to carry it toward the Paper machine.

What is the Paper Machine?

A tank of half-stock supplies a long series of wire-screen, driers, ten or more large steam heated cylinders, and a dozen small hot iron rollers or ironers called calendars. It is said that the largest or longest machine in the world is a Paper

machine now running at Niagara by power from the Falls. The flowing stream of white liquid gradually sinks through the wire screen and the vegetable fibres, with their sizing, cling together as they are left on the screen. They are continually pressed until they become thin enough and dry enough to roll on the great "spool" that goes to the newspaper office. The Foudrinier apparatus may be divided into three great parts, beside the tank and sand-trap, where the "milk" flows. First, the wire-screen, with felt under it, and then with sucking cylinders under it, so that the water not only runs through the sieve, but is also sucked out with vacuum pumps; second, the big hot cylinders, heated with steam; third, the little hot cylinders, or calendars, that iron and smooth the paper.

Is this cheap Paper used for Books?

Yes. Nearly all the paper-covered novels are thus made, and there is a tendency among the makers of the cheap magazines to intersperse among the sheets of fine paper on which pictures are displayed, sheets of the better order of wood-pulp paper on which only text is printed.

How are rags turned into Paper?

They are carefully sorted, beaten in a machine, boiled in caustic soda for half a day, picked again by women, and put with water in the breaking engines. Wheels armed with knives play into other knives, chloride of lime is added, and a whitish pulp is gradually made. This is run off into stone chests, where it grows whiter, and after twenty-four hours is pressed to take away the most of the lime. It now goes to the beating engine.

What is the Beating Engine?

It is a second breaking engine, with finer knives. Water is again added, and with it the earths that are to be loaded on the Paper, if it is to have a high glaze for printing. The machine goes for from four to six hours. China clay and pearl white were the earliest loads. It is now ready for sizing and coloring.

What is a super-calender or plate Paper?

Where paper is to have a glaze of either gelatin or earth on its surface or surfaces, it must be submerged in a bath after it is

MAKING THE CELEBRATED TESUKIJUMI PAPER—JAPAN

made, and must pass over another set of rollers. In some mills, it seems, these drying machines extend to a series of more than two hundred rollers. The plate Papers, with a coating of polished clay on a light rag Paper inside, now carry the modern half-tone photographic engraving to perfection with the least weight, the greatest beauty and the smallest expense; and the sizers seem to put a velvet polish of almost metallic hardness on thinner and thinner stock.

How is Paper cut?

The modern newspaper saves the mill man the expense of cutting, but nearly all book work on sized Paper is printed from sheets, by the ream. The cutting machines at the Paper mills hang four (or more) spools on one cutting machine, reel the four together on one cylinder and cut the four sheets at once.

How is Paper water-marked?

The figures or letters you see in some Papers when you hold them to the light, are stamped in by a "dandy" roller while the milk is passing across the perforated sucking rollers in the early part of the journey through the long Foudrinier machine.

What is hand-made Paper?

A man dips a sieve in the milk or half-stock. Lifting it, he has a sediment of fibre. This he tips over on a board, and then irons it between rollers. If his sieve have figures woven in it, there will be a water-mark in his paper. Hand-made Paper nowadays is possibly an affectation.

What makes the glaze on Writing Paper?

After the Paper leaves the first machine—whether it be the Foudrinier rollers or a hand-sieve, it is dried or aired, if necessary, and then it is passed through a bath of nearly thick or strong gelatin. As it leaves the bath, it goes through press-rollers to wring off the extra gelatin. Now it is slowly dried at 80 degrees, and calendared between hot rollers, or it can be pressed or rolled between sheets of polished metal. In American calendaring machines, one of the rollers in each set may be of compressed paper or cotton.

Does the Paper Machine rule my Writing Paper?

No. The rulings on writing Paper and on blank books are made by drawing the Paper in sheets under ranks of small hair brushes or pencils in a ruling machine. The ink used is very thin and weak in tone, nearly always a very light blue. The Paper travels on a moving belt or bed, under the line of brushes that drags or lies on the Paper.

To what great uses, beside the transmission of information, is Paper put?

For decoration, for casting, and for wrapping. The coloring and printing of wall-Paper and the casting of Paper into forms for walls and ceilings has altered the methods of house-building.

Is Wall-Paper old?

Yes. It is a Chinese device. But it was not until late in the eighteenth century that Paper could be made in long strips. Printing with wooden blocks has been but slowly displaced by machinery in England. In America, our wall-Paper has long been cheap and beautiful. With its borders, friezes, centre-pieces and mantel-backings, it has given a field for the art and skill of the paper-hanger. Dark papers should only be hung where the light is very strong. Metallic backgrounds will be found to endure.

What are the methods of making Wall Paper?

The white stock is made on narrow metal cores, in rolls, weighing, say, two hundred and fifty pounds. This goes to the wall-paper factory where it is dyed and printed, nearly always by machinery, on engraved cylinders. The metal core goes back to the paper mill. The wall-paper factories of the West have flourished, even outside of the trusts, and have done a cash business.

What great thing did Papier Mache do?

This paste of Paper stock, because it could be pounded with a brush into the face of a form of newspaper types, enabled the publishers to run a number of presses at once. In the old days, two days at least were required for electrotyping a form. The *papier*

mache process was at last reduced, by a steam drier, to a few minutes. In New York city, a journal has thus been able to duplicate its presses until it has printed and circulated 750,000 copies, each copy having five parts or press-works, in one day. The *papier mache* matrix is only a thin sheet of paper, after all. It is bent as it is put in the mold, so that the type metal plate cast from it has the curve of the press cylinder.

What else is papier mache used for?

Lead-pencils, "straws" for beverages, car-wheels, cigar-boxes, buckets, shoes, rims for bicycles, stage furniture and architectural decorations.

Where are false faces made?

Largely in Paris. Labor costs too much in America. Models are made in clay, and from these molds are taken. Sheets of wet Paper are wrought into the sinuosities of the mold, the mold is dried, and the mask is painted by different painters. It is all hand-work. Vast numbers are imported to America.

What is Straw-Board?

It takes the place of what was once called paste-board. Its manufacture created an interest so great that the American Strawboard Company was organized, and for decades its shares have been a speculative property on the exchanges of the large cities. The use of straw-board for boxes, packing (especially of eggs), transmission of fragile flat articles in the mails, and for other purposes, is a characteristic of modern life. Paper of any make can be run through paste, doubled and pressed into any requisite degree of thickness or solidity.

What is Tesukijumi paper?

It is the finest quality of hand-made Japanese paper. It is made from the fibers of the bark of the Mitsumata plant. It is beautiful, glossy, strong and not easily broken, even when wet. It will last through many centuries without decay and is free from attacks of the paper moth. It is especially valuable for paper currency, bank notes, etc.

Fig. 164. THE POTTER.

China.

What was Man's first Dish?

Probably a sea-shell, beautifully lined with mother-of-pearl. This glaze Man has not yet been able to transfer from the shell to his most costly porcelains. The early dishes of inland men were flat stones, and then stone bowls, gradually worn out in the centre by the grinding of grain.

What People first made White Dishes?

The Chinese, who closely guarded their methods. It was only in the eighteenth century that the Kings of Europe were able to make similar wares.

What is the difference between Glass and Pottery?

Glass is dealt with while in a melted state. Pottery is molded and only half turned to glass, under the subsequent action of heat. But Pottery is the most lasting of man's handiworks.

What is a Glaze on Pottery?

A coating, usually of glass. The common white earthenware dinner plate was molded in clay and then dipped in the glaze. Then it was fired in the kiln or perforated oven.

What is a Flower-pot?

It is simply baked clay, porous and without gloss. It is like a brick. One of the signs in the Zodiac—the Twins—stands for the month Sivan—meaning the making of bricks, the foundation of the city, and the Fratricide, or brother-enemies, like Cain and Abel, and Romulus and Remus

Why did the Egyptians put straw in their bricks?

The straw burned out in firing, leaving the brick still more porous. Thus it was lighter, and would hold more water, making it cooler in houses. Where there were no rocks, as in Mesopotamia, brick-making must flourish. But the oldest brick structures, as at Sakkarah, in Egypt, contain fragments of older clay dishes. In 1896, a society of Philadelphians, digging at Nippur, found a vase nearly ten feet high, and they believed it to be of a date more than 4,000 B. C.

What device was used in making these Dishes?

The potter's wheel. By setting a wheel so that it would go round horizontally, and making an axle or pole that would hold a sufficient amount of clay, the clay could be whirled rapidly, and the potter, with his thumb for chisel, could give a symmetrical outer form to his vessel. Later, the wheel would be put where the feet of the potter could turn it. Both these forms of potter's wheel are shown in the pictures of the Egyptian tombs. The poetic simile "like clay in the hands of the potter," used in the Bible, comes out of Egypt, where the god Phtah, it was believed, made the mundane egg on the potter's wheel.

What are our Stone Crocks made from?

First, the clay is largely silicon. The glaze may be of salt, or a lead glass.

What is it that makes China or Porcelain?

The whiteness, hardness and fineness of the earths or sands used by the potter. Deposits of these white earths must be found before a pottery can make good wares.

Define some of the commonest terms used by the Potters?

The *paste* or *body* is the "clay" used in molding the vessel on the wheel. *Biscuit* is clay only once baked, with no glaze—a misleading term, as it means *twice cooked*. *Slip* is a thin mixture of "clay" and water, into which the molded article may be dipped, or with which it may be ornamented before firing. All our China consists of a *body* and a *slip*. *Enamel* is a glaze that has been made opaque, usually by tin oxides. All *glazes*, as such, are to be considered transparent, whether colored or plain.

There are ancient Greek paintings of a potter applying colored stripes to the clay on his wheel by means of a stick or brush, the wheel whirling meanwhile.

Were the Ancient Potters expert in molding?

Yes. They possibly developed the number of patterns far beyond the use of modern molders. Their forms were both delicate and beautiful in archaic times. Greek sculpture, at a later date, lent its triumphs to the potter's art.

What finally resulted, touching our homes here in America?

The potter's art was gradually turned toward the ennobling of our common table ware. First, a cup and saucer, a plate, or a mug, of dainty design and excellent workmanship entered our homes at Christmas-time. Then whole tea sets of golden-rimmed China were possessed, for state occasions. At last, the China offered to the common people is of a kind that would have excited the envy of Kings a few centuries ago, and only the question of *care* enters into the problem of owning such utensils.

What did our great-grandfathers eat on?

Usually on silver or pewter plate. A few of the people had sets of the rude, blue China, made by the Dutch, in imitation of the Chinese ware

How did the Western nations learn of the Chinese Pottery?

Pere Dentrecolles, a missionary, gives the first European's account, in Du Halde's Description of the Chinese Empire. Father Du Halde was secretary of the Jesuit Society that sent out the missionaries.

I am curious to know about this Chinese art as it was practised at home.

The first porcelain furnace on record was in the province of Keang-Si, the same province that now leads in the manufacture. The felspar clay called *Kao-lin* by the Chinese was called *porcelain* by the Spaniards, after the porcellana shell. The shell was named from *porcella*, Spanish for *little hog*. Du Halde did not believe that the Chinese words for their blue and white substances could be translated.

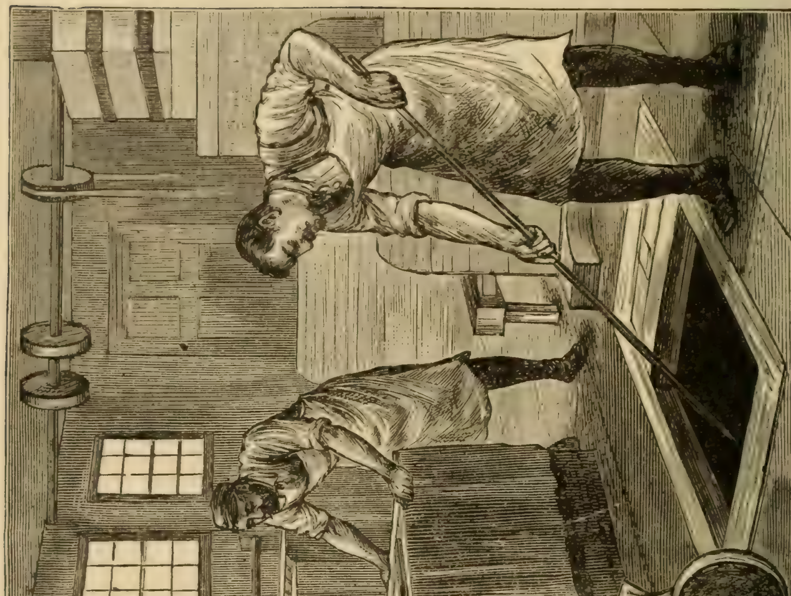


Fig. 165. THE SLIP HOUSE.

What did Father Dentrecolles see?

At the city of King-te-Ching (near Mount Kao-lin) there were three thousand ovens in operation, with great multitudes of workmen. The Chinese used two "clays" in each dish—one was the white earth found near the mountain of *Kao-lin*, whence its name. The other clay was *pe-tun-ste*, and it is not yet known what that is. How they prepared their famous, rather ugly, blue color is not exactly known. A great lake, three hundred miles in circuit, furnished the only water with which the potters could make their best Chinaware. The same workmen and clays produced inferior Chinaware with the water of other places. No stranger was permitted to visit the borders of this lake, which had probably deposited the sand called Kao-lin.

Who was Marco Polo?

A Venetian historian, who traveled in Asia five hundred and fifty years ago. Following is his passage on Porcelain: "Of the City of Tin-gui there is nothing further to be observed than that cups or bowls and dishes of Porcelain-ware are there manufactured. The process was explained to be as follows: They collect a certain kind of earth, as it were, from a mine, and laying it in a great heap, suffer it to be exposed to the wind, the rain and the sun, for thirty or forty years, during which time it is never disturbed. By this it becomes refined and fit for being wrought into the vessels above mentioned. Such colors as may be thought proper are then laid on, and the ware is afterward baked in ovens or furnaces. Those persons, therefore, who cause the earth to be dug, collect it for their children and grand-children."

What does the Chemist find in a Chinese Plate of the finest kind?

Silicon, aluminium, potassium, iron, oxygen, and a trace of magnesium. That is, pure sand (of granite), pure clay and potash are the main ingredients, at the ratio respectively of about seventy, twenty and sixty. Copper and cobalt were both used in the blue. (See Chemistry.)

What is Kao-lin?

Granite or other igneous rock has been decomposed by water

The quartz and mica have fallen to the bottom of the stream. The fine silicate of alumina and potash has stayed in the water longer, settling into Kao-lin wherever there was a pool. At the bottom of this pool beds of Kao-lin formed. Kao-lin is the hydrated (watered) silicate of alumina. Its atoms are theorized as follows: Molecule 1—two atoms of aluminium and three of oxygen; (this is closely united to) Molecules 2 and 3—each one atom of silicon and two of oxygen; Molecules 4 and 5—each a molecule of water; the whole molecule giving the following formula: $Al_2 O_3.2SiO_2+2H_2O$. In firing, the water goes out. This white earth was sifted and pulverized until it became as fine as flour.

How did the Chinese prepare their Slip for the Glaze?

With especial care. This slip was Kao-lin with a potash or soda in it, so that the soda or potash would melt in the fire. The *slip* was mixed thin and gradually dried to a doughy consistence. Then it was kneaded and trodden under bare feet. Any vegetable substance would burn out, leaving a pore or fault in the glaze, therefore, the Chinese place the stock in a damp place, where it may ferment and decompose. This occupies years, the Chinese believe, and the father leaves his son stock enough to last a life-time.

How were the Blue Pictures put on?

By a set of artists, each making a different part of the picture, owing to the influences of caste and unionism in the trades. When the Chinese began to paint pictures to please the Europeans, the effects were still more grotesque, as all the bad features of the bad European engravings which furnished the original copies were faithfully reproduced.

Describe, briefly, the entire Chinese Process?

With a quantity of the Kao-lin the Chinese potter "throws" his vessel on the wheel, using such molds as may be useful, and such hard instruments as will shorten his labors. The article is then set to dry. The painters now apply their blue figures and landscape. The *slip* fluid is now blown on with a pipe, as the Chinaman loves to spray things, or the article is *dipped*. As we

have shown, it is with the fineness and purity of this *slip* that the Chinaman charges his famous patience. He has ground and ground in water the heritage left him by the ancestor whose

Fig. 166. PORCELAIN—THE DIPPING ROOM.

memory he so religiously reveres. The new vessel, painted and varnished with *slip*, is now packed in a clay box called a *sagger* in English countries, and the *saggers* are piled up in the kiln. The surrounding of clay in the sagger keeps off the smoke of the

firing. The firing goes on for over a day, and the cooling also goes forward slowly. Now if the cup is good, it may be gilded. A band of gold leaf may be laid on the upper outer edge, on sizing, and the cup must be fired a second time, but in a more open kiln with less heat. After the cup comes out, the metal band must be polished with a hard stone instrument. Painting may be done over the glaze, and much of the early porcelain that came from China was thus "improved" by French painters, greatly reducing its present value to collectors.

What were the medieval Western Potters doing?

They were making vases and ornamental articles. Famous potteries existed on the Balearic Isles, where Majolica ware made its fame. Sand from the bottom of a river was used, making a red ground work. Sand and cream of tartar or wine lees were made into glass (enamel), and the glass might be whitened with tin oxides. To decorate the article, the enamel could be cut through until red lines appeared.

But how did our fine, white, useful dishes get westward from China?

About 1700, John Schnorr, a wealthy iron-master, riding near Clue, found a remarkably fine, white earth in the road, and determined to use it and sell it for hair-powder, instead of flour. It happened that an alchemist named Botticher or Bottiger used this hair powder about 1700, and detected its earthen character. He accordingly made a crucible out of it, and to his astonishment, the crucible turned into Chinese Porcelain. As all Europe had long been on the lookout for the solution of the Chinese mystery, it may easily be conjectured that the Elector (King) of Saxony, listened with pleasure to the revelations of Botticher. The Elector himself took an oath of secrecy. A fortress was built at Meissen, near Dresden, with portcullis and drawbridge. "Dumb Till Death" was inscribed in all the workshops, and a penalty of imprisonment for life was denounced against any person who might tell the tale. The white earth was brought from Clue in sealed packages under misleading names, and real China-ware—the first of the famous Dresden China—began to come out of the fortress. At the World's Fair of 1893, the Royal Saxon

potteries exhibited their manufactures, but their art seemed to have developed into the making of artificial flowers rather than table ware. The great Porcelain Porch, in the Imperial German Exhibit, outdid the famous Porcelain tower of Man-King in China.

Did Botticher's secret escape?

Yes. The Emperor of Austria finally founded a factory at Vienna, but it never succeeded fully. To start it, a workman escaped from the prison-like works at the castle of Meissen about ten years after the first Porcelain was made. The Viennese royal pottery ran, however, till 1864.

When did the King of France start his Porcelain Factory?

In 1753, when a semi-private factory at Vincennes was removed to the town of Sevres, in the suburbs of Paris. The French chemists actually prepared an artificial Kao-lin, and used it for

Fig. 167. GILDING THE PORCELAIN.

the *biscuit* until the German secret came out and French Kao-lin was found in 1770.

How was the Sevres Kao-lin made?

White sand, 60; nitre, 22; salt, 7.2; alum, 3.6; soda, 3.6; gypsum, 3.6. This compound was roasted at a high temperature, then ground to a fine powder, and washed with boiling water. To nine parts of this mixture, or *frit*, two parts of chalk, and one of a pipe-clay were added. This mixture was again ground, and passed through silk sieves. It was mixed for molding with water and soap or size, and in this condition was operated on by the potter.

How does the Sevres Potter proceed?

If making a set of plates or saucers, he takes the potter's wheel, exactly as the later Egyptians did, and turns it with his feet. A mold of a plate is set on the wheel. For illustration, let us (incorrectly) suppose it be a plate exactly like the one he is to produce on the wheel. The mold, then, is turned bottom upward. On the bottom of the mold, he spreads a very thin layer of Kao-lin, and as the wheel revolves, he smooths, levels and marks the Kao-lin with a steel template, or gauge. All the while, he dips his hands in the *slip* at his side, and holds a sponge wet with *slip* to the surface he has made. The template enables him to make the circular ring and the basin or *mesa* that is inside the ring. Of course, the mold cannot be an actual plate, turned upside down, for that would mold a *ring* in the new plate. So we see the potter turns or lathes the bottoms of our plates, and molds the upper sides of them. There are about two hundred and fifty potters and painters at Sevres, and they call their *slip* "barbotine." The painters are all artists of unusual ability.

What is done with the dry Sevres plate?

It is put on a wheel or lathe and smoothed with sand-paper. A teacup gets its handle at this stage. The little handle is cast in a mold which comes in pieces like a glass mold. The little handle is affixed to the bowl with some of the *slip* now used as a "lute" or solder. The modeler now takes the vessel or plate

and corrects any distortions that he may detect, working with modeler's tools. Groups of small statuary are cast or molded to this stage.

Describe the Kilns at Sevres.

An oven that bakes China or Pottery of any kind, should let

Fig. 168. PORCELAIN–BISCUIT SCOURING.

the fire through its bottom—it burns rather than bakes. The kilns at Sevres have four stories with three ovens, and all the

floors of these three ovens are perforated. The fire of coke or white wood is in the lower story. Our "raw" plate and cup go in the top oven, where the heat is least. But the raw articles are placed in porcelain jars or boxes (*saggers*), and the boxes are piled high in the ovens. The lower ovens are filled with articles that are further along in the process. There are windows of talc (a magnesium mineral—soap-stone), through which the potters observe the effects of the firing, and there are means for taking out samples. The fire is kept up for about thirty-six hours, and the ovens cool for nearly a week. Our plate and cup are now *biscuit*.

Describe the Sevres Pate-sur-pate decoration.

If the painter now take the *biscuit* and tint it a certain hue, and then paint on the tint with the white outer porcelain glaze, which we have not yet arrived at, he will give an additional and cameo-like ornamentation to his work. The *pate-sur-pate* (*paste-on-paste*—that is, Kao-lin on Kao-lin) must precede the glaze.

Describe the Sevres Glaze.

Felspar and quartz crystals have been ground into powder with water. The pure silica (silicon and oxygen) is mixed with water. The plate and cup are dipped until they have acquired a coating of the white sand (silica) and dried. The vessels now go in a kiln where they occupy the lower oven, with a heat of over 3,300 degrees. The white sand melts, and getting its alkali out of the *biscuit* underneath, forms a glaze.

What colors does the Sevres painter put on top of the glaze?

Painting over the glaze permits the use of a great range of metallic colors. The blues are from cobalt, the turquoise color from copper, and the violets from manganese. Different pigments will endure varying degrees of heat, so that those which require the hottest fire must be put on first, and there are three such fires—the grand fire, the half-fire and the muffle fire.

How is the Sevres Gold put on?

A chemical solution of gold is made, and the metal precipitates under the firing, and is then burnished. This must be in

BURNING MEXICAN POTTERY.

a special kiln, with the hottest fire, therefore the first of the painter's fires. Many of the finest potteries of the world, as in Belgium, have gold paper edging that is laid on the plate and burned away, or may come away soft. This method has greatly beautified the golden decorations of our Royal Worcester and Limoges plates, cups and saucers.

What are the Sevres Painter's difficulties?

His colors change in firing. His vessel must undergo at least six firings, and where it needs correction, must be fired a seventh time, with risk each time of destroying all the work that has gone before.

Where do the French and Belgian Potters obtain their Kao-lin?

From Limousin, France, and Cornwall, England. The Cornwall clay merchants proceed as follows: The decomposed felspar of granite is found as a stone and broken up, and laid in running water. The fine clay that is wanted floats with the water, while the quartz and mica sink. The water runs to a pool, where the white clay settles. The pool is drawn off, and the clay is dug out in blocks and dried. It is then ground into an impalpable powder. The powder is mixed with water into a dough, which is beaten and kneaded and sifted, like *slip*.

How is the Flint prepared, which is often mixed with the Kao-lin?

This probably represents the *pe-tun-ste* of the Chinese. The flints are burned in a kiln, and thrown red-hot into cold water. They are then ground into fine powder. This powder, mixed with Kao-lin in water, is dried. In the flint there is or once was much vegetable matter. After the kneading, the mixture must be cured by time, as the Chinese do it. Slip is made out of this compound of flint and silica, with possibly an alkali and a metal that is not acid.

How do the Japanese make such thin cups?

They dip the mold in a thin solution of the Kao-lin, until a film has gathered of sufficient thickness to stand alone after firing. Their clays are never of the whitest kind.

What is the Cloisonne ware?

The Japanese, after the first firing, make a tracery out of brass or copper. This they affix to the clay vessel, so that the brass projects in lines. Then the enamel is laid in between the lines until the surface is just level, with the brass lines showing.

How do the modern English and American Potteries differ from Sevres?

Very little. Mainly in the mechanical application of the decorations. Let us suppose a plate is to be *printed.* The design is engraved on a copper plate. The pigment (paint) is ground fine and mixed with a very sticky gum in oil. The pattern is printed, in this oily ink, on tissue paper. If the pattern is for the edge of a plate, it has a lace fringe on the inner edge and is printed on a strip of paper. The strip is applied to the *biscuit* or clay, face downward, and the scallopy edge of the lace enables the operator to conceal the curves in his strip of paper. Centre-pieces, of course, give no trouble The paper is washed off with water, and the plate is baked, to burn out the oil in the color. The glaze goes on top of this. Collectors abhor the mechanical decorations, because they can be duplicated so easily, but many of our handsomest golden decorations betray the aid of the lace-paper. Painting under the glaze both softens the effect, and makes the colors as lasting as the plate.

Did America furnish any fine clay?

Yes. The early English potters like Wedgewood obtained "unaker" from our land. Kao-lin has been found in many of the Eastern States and in Nebraska. The calico-bleachers and the wall-paper printers use it. The first American bed of Kao-lin was found at Monkton, Addison County, Vt., in 1810. In 1819, Dr. Mead found Kao-lin in New York. In 1827, it was found near Pittsburg and a pottery established. A bed in Chester County, Pa., was the foundation of the American Porcelain Company, under Tucker and Hemphill.

What did the World's Fair bring?

The exhibits of Belgium showed cups and saucers and dinner sets of the most admirable translucence and coloration. The

Republic of France exhibited the vast blue Sevres vases owned by the nation. The English dinner plates were somewhat heavy, but their golden decorations were possibly the finest. The Japanese pottery was the finest in weight, and far the cheapest ware ever seen. Of the vases, the French, Saxon, Spanish and Japanese competed. For elegance, possibly the French excelled; in prolixity of decoration, the Saxons led; in patience, the Japanese. The large vase, as we see it, is philosophically a variation of the oil and wine vat and coffin of Asia into an article of pure ornamentation in the Western nations. If that be true, its existence as a probable product of future ages is threatened.

What are the modern colors which the Chemist produces for the painters of Porcelain?

The oxides of cobalt, iron and chromium give the stablest colors for painting under the glaze, with great heats. All hues can be produced over the glaze, where they wear off. But all must be mixed with a flux, and carbonates of soda and potash, oxide of lead, borax, nitre, etc., are so used in the pigments. Oxide of zinc is used with the other colors to modify their shades and tints. For blue and gray, up to black, oxides of cobalt. Antimony and lead give yellow. Oxides of copper give deep red, or brilliant blues and greens, according to the atoms of oxygen. Oxide of chromium produces a soft green. Manganese gives violet, and even black. Gold gives a fine ruby red. Uranium offers a rich orange. The oxides of iron produce all sorts of reds, yellows and browns. Thus, Chemistry plays as important a part in the beautifying of our table-ware as in the decoration of our cloths and our walls.

What are Tiles?

Thin bricks that were formerly used for the roofs of houses and for pavements. The palace of the Tuilleries at Paris, occupied a site that was once a tile-yard. We use tiles for mantels and fire-places, and sometimes for fancy pavements.

How did the ancient brick differ from the modern one?

The ancient brick was a quadrangular plate. It was about ten

inches long, eight inches wide, and only two inches thick. Its edge was often enameled with brilliant color, even at Nineveh and Babylon.

Do we use Enameled Bricks?

Yes. A white enamel is put on the edges of bricks for the walls of courts, and for the lower parts of the walls of corridors in great buildings.

Do we use Mosaic Pavements?

Very largely. It is said that there are 50,000,000 small pieces of baked clay in the Pompeiian mosaic floors of the main Auditorium Building at Chicago. The pavement thus laid is more durable than the tile mosaics that were formerly used.

What is Terra Cotta?

These words are Italian for *baked clay.* In our language, Terra Cotta embraces all that class of brick manufactures used to cover brick walls, and to surround iron columns. An increasing quantity of this brick-ware is used for partitions. It is cast with two flues in each piece, and is capable of withstanding great heat while the air is passing through the flues. It is nearly as difficult to thoroughly heat clay as water.

Matches.

How early in his history did Man build fires?

Not even a trustworthy tradition comes down from a time when man did not build fires with comparative ease wherever he might chance to be. It is not impossible, however, that the sacred fire or lamp at the Temple was instituted for a social rather than religious purpose, if the two things were not one. The sacred fire may be traced downward to Scotland and Ireland, where it was renewed and divided on the night now called Hallowe'en—the autumn or harvest festival.

Who was Prometheus?

The Greek story of Prometheus, who stole fire from heaven, is only a reiteration of far older fables touching the worship of trees, or Arborolatry. The universe was a tree. Fire was its fruit, and its leaves distilled the water of life. The gods used the fire for themselves. Thus, he who stole this fire was accursed. At this time, it may be, the priests alone used fire.

What did the Egyptians and Hebrews use?

The "lamp of fire," as in Abraham's dream. This lamp was carried through the wilderness. We see it still at Rome in the regia and the temple of Vesta.

How did the family or gens arise?

Probably when tribesmen who were not priests were allowed to build a hearthstone of their own. The fire on this hearthstone was renewed at Hallowe'en (so-called now), because man believed that fire must grow old.

Did man become expert in starting this fire?

Yes. By friction, with sulphurous, iron and potash metals, in every clime, man learned to make a spark, and throw that spark where it would catch fire. But this operation, especially in wet

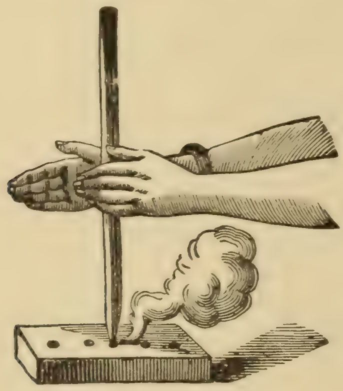


Fig. 169. STARTING FIRE.

weather, was so difficult that the sacred or ancestral fire (as in China and Corea) soon became an established thing, with specially deputed lamp-bearers. In Europe, to-day, there still remain on many farms, fire-pits, where fuel is furnished all the year round, in order that the fire may not go out. The burning sun-glass is older than Greece.

What was the commonest fire-starter of the middle ages?

The flint and steel, a product of the stone age, when chipping the weapon brought forth sparks of fire. The spark was cast into a tinder-box.

What was Tinder?

Scorched linen or cotton—that is, carbonized fibre. The spark caught in the tinder, and would set sulphur on fire, or would blaze up itself. The muskets with which Napoleon won most of his battles were furnished with flints, and the soldiers of Marlborough set off their guns with a punk, as boys now light fire-crackers. Percussion caps were patented in 1807.

How do you think the Match evolved?

Man obtained fire from burning naphtha wells, from burning bog, from burning forests, etc. He saw the sparks fly from his flint weapon, and saw them set fire to fibres. He lived where sulphur was abundant, and noted its affinity with fire. He set sulphur on fire. The axle of his chariot took fire, and he learned to rub two sticks or whirl a stick against wood. Finally, sulphur was tipped on sticks, at volcanic craters or at mines, and when the flint spark flew in the tinder, the sulphur match was touched to the spark and blazed. Then it was found that the sulphur match could itself be lit by drawing it through sand-paper. This was the brimstone match of our grandparents.

Where is the great variation in the development of Matches?

The introduction of phosphorus and potassium and the adoption of a bottle match in place of the tinder-box. Phosphorus was put in a bottle, a hot wire was run in the bottle; the phosphorus oxidized on the sides of the glass. Now, if the sulphur match were run in the bottle, when it came out it would be in flame. The chemists knew this one hundred and fifty years before it became useful to the people. Many other chemicals would produce the same result on the sulphur match. In this way, the match-makers became familiar with the fire-making properties not only of sulphur and phosphorus, but of chlorate of potash, red lead, nitrate of lead, bichromate of potash, peroxide of manganese, sulphide of antimony, saltpetre, charcoal, sugar, etc.

What is the history of Matches in America?

The Locofocos, or Brimstone Matches, were brought to America about 1825. A piece of sandpaper was sold with a comb of Matches.

What was the Locofoco made of?

The stick was dipped into suphide of antimony and chlorate of potash mixed with any gum. The Americans at once improved the apparatus by putting the matches in a box, and pasting the sandpaper on the box.

Where did the wooden Phosphorus Match of the present day come from?

It was made in large quantities at Vienna, in 1833. Lundstrom, of Sweden, in 1855 began the use of red phosphorus, which reduced the evils of Match-making.

What is a Safety Match?

Usually an apparatus in which the phosphorus is contained on the scratch-paper accompanying the box or on the box of Matches. These Matches are particularly obnoxious to persons who supply their pockets from match-safes at counters in restaurants, etc., and though the use of such Matches is economical on that account, still proprietors of establishments depending on public good will are slow to set forth the Safety Match to the public.

Do we make our own Matches in America?

Yes, and export a considerable number. The making of Matches was consolidated into a trust before the war-tax was taken off them (in 1883), and the shares of the Match companies became one of the leading speculative properties of the stock exchanges.

How are Matches made here?

As in Sweden, Germany, Austria-Hungary, France and Great Britain. The pines, aspens and poplars furnish the favored woods. The square Matches are cut from a veneer of wood. The round matches are made by forcing a block of wood against a steel plate with holes in it. In both processes, the wood has been boiled and shaved, as if fruit baskets were to be made of it. (See Fruit.)

What is done with the sticks?

They are fed into lathes which arrange the sticks so that they do not touch. A frame holds two or three thousand Matches. A man holds the frame so that the Matches become hot. Then he dips the frame so that the tips of the Matches go into melted paraffin. Now they are dipped into the phosphorus mixture. When dry they are ready to be packed. The modern round Match does not seem to often set fire to houses, even in the

hottest weather, or with the most careless handling. However, household match-boxes should always be large and of metal or china, and supplies should be invariably kept in metallic or earthen receptacles.

What is peculiar of Matches in France?

The Government reserves the monopoly and sells it to a Match Trust, called *La Compagnie Generale des Allumettes Chimiques.* This Company has twelve factories, and the largest are at Marseilles. Matches in France are dear, and the French use fewer than any other civilized people.

Was there any Match-cutting machinery at the World's Fair of 1893?

The display in the German Section of Machinery Hall included machines that would cut fifteen million splints a day. One English factory makes thirty-six billion Matches each year. A block of hot soaked wood as long as seven Matches may be shaved into a veneer, and the chopping-knives may afterward cut out two hundred to three hundred Matches at a blow.

How many Matches are made?

Europe consumes about twelve hundred tons of phosphorus in Matches each year. In some nations, each inhabitant seems to use seven hundred Matches a year, and America leads the other countries. Undoubtedly, the habit of smoking, the growth of cities, the high winds of the West and Northeast, and the wasteful tendencies of the age, conspire to increase the consumption of Matches.

Fig. 170. SIR ISAAC NEWTON.

Astronomy.

What do we see at night?

If an inhabitant of this little world of ours look upward on any highly-starlit night, he is confronted by a portion of the grand Universe,—a field far surpassing the utmost conceptions of his imagination. Stars of varying degrees of brilliancy bespangle the whole concave of heaven, but across the central portion of the expanse, stretches a misty zone or band, the cause of which is the marvelous multiplicity of light-giving worlds in that zone. This Milky Way is found, upon circumnavigating our World, to entirely surround us, leading the Astronomer thus to determine that the outside Universe is shaped like a cheese or grind-stone, and that our position in that cheese or grind-stone is nearly central. Looking toward the Milky Way, we are looking from the center of the cheese to the rim, and of course looking the longest way out of the cheese and encountering the maximum number of Stars. Again, looking the nearest way out of the cheese, we behold the Stars vastly less frequent.

Where is the Sun?

Centrally, in this Titanic cheese made up of Stars, each one of which is incalculably distant from its nearest neighbor, is placed our Sun,—a Star undoubtedly of the average size, but certainly not one of the largest. The enormous prominence of this fiery orb in our eyes, is entirely due to the close view which it is our fortunate lot to have of him.

Has the Sun satellites?

Yes. Around our Sun swing a large number of smaller and

wholly-dependent bodies. Many of them are Comets, and a large group (called Asteroids) are apparently fragments of a once great Planet, for they travel around the Sun in close company with each other, and present irregular forms. The motions of the bodies composing the Solar (the Sun's) System are not the regular circles which the pre-disposition to order and symmetry in the human mind would naturally prescribe, but seem to be a compromise of the differing impulses of every one of a great number of orbs.

What are the peculiarities of the Comets?

The tribe of streaming dependencies called Comets, in their unceasing course, seem by turns to speed directly at the great central luminary, and then, after barely escaping a collision with the Sun, to whirl around that body and rush out as directly into the unknowable regions of space between us and the nearest Star. Of these Comets, the Astronomer knows little. Only the "short ends" of their orbits or paths are within the more circular orbits of the Planets, and the other ends reach into the unknown. A few of these strange bodies have made trips enough to establish the fact that their orbits are diminishing in size, and that the friction of their rapid passage is subtracting from the impetus with which they began their erratic careers. They are found also to be the merest gas bags, the air of our Earth being sufficient to repel them should they come in collision with this Planet. They can easily be seen through with the telescope. The fact of their succumbing so readily to friction on account of their feathery lightness, has furnished a general law, and it is believed that the orbits of all the Planets are gradually closing in.

How are distances computed?

The paths which the ordinary Planets follow in space, as indicated previously, instead of being the perfect circle, more closely resemble the ring which the school-boy draws on his slate, lop-sided, long and helplessly misshapen. Therefore, in the mention of distances which is occasionally necessary here, it is to be remembered that true distances in Astronomy differ with every difference in the time of the year, month, day, hour,

minute and second. The learned Astronomer strikes an average for general purposes, and the outcome of general calculations is not disturbed by the especial inaccuracy.

Where is the Moon?

In order to speak understandingly of the Sun, which naturally comes first in the Solar System, it is necessary to say that the Earth, the third nearest child of the great light of day, is in turn the mother of a smaller body (the Moon). This Moon is 238,000 miles away from us, or nine or ten times around the world. A man with our facilities for traveling around the Earth could make the trip to the Moon and back after arriving at manhood.

What can be said of the Sun?

The magnificent orb which is the most remarkable spectacle presented to the gaze of man, is also the very fountain of his well-being. In return for the unremitting favor of the Sun's nourishing warmth and unequaled brilliancy, man in various ages has felt impelled to offer by turns the full measure of his willing idolatry, wonder and admiration. The first astonishing statement relating to this great luminary is to be made in attempting to impress his size upon the mind of the inquiring reader. He is found to be 866,000 miles in diameter, or over 2,598,000 miles around at his equator, or largest belt. These figures are so compact as to carry little import to the mind, but there are happily, other aids to a proper conception of the fact. The Sun, measuring as above, is 1,273,000 times as large as the Earth, and, if all the planets were melted into a ball, he would still be 600 times as large as their combined bulk, although one of the Planets (Jupiter) is 1,233 times as large as the Earth.

Compare the Earth and Moon with the Sun.

If the Earth were placed in the centre of the Sun, and the Moon were put at her proper distance, 238,000 miles outward, she (the Moon) would revolve within the crust of the Sun a distance of over 191,000 miles, leaving by far the greater portion of the Sun's mass outside of her orbit. In looking from the Earth to the Moon, this statement can be profitably borne in mind.

The Sun does not weigh proportionately to its bulk. While it is 1,273,000 times larger than the Earth, it is only 325,000 times as heavy. The heat given out by the Sun is prodigious beyond all idea of combustion. The successful burning of tons and tons of coal in every second on every square inch of the Earth's surface would secure an insignificant comparison with the flames of the Sun, owing to the superiority in size of the celestial colossus. His light is found, by measurement, after traveling 92,800,000 miles to the Earth's

Fig. 171. PARHELIA, OR MOCK SUNS.

surface, to have the power of 5,550 fine candles placed a foot away from the point to be lighted.

What is seen on the Sun's surface?

While the Sun presents a beautiful, glossy surface to the suffering eye which presumptuously peers at his majestic glory, still a more critical observation through the telescope discovers

a most seething inquietude. Vast gorges and holes into which this petty world and all its planetary fellows could be heaved, suddenly appear in the surface, and then as suddenly do the tormented billows of effulgence sweep together, leaving no trace of the event. At the distance of 92,000,000 miles these gaping holes for worlds become merely "Sun-spots," and, when not so fleeting as to immediately disappear, or where they are permanent, serve to demonstrate clearly that the Sun turns around on its axis, thus showing himself at least to be amenable to one of the laws governing less important voyagers in space. The fact of his rotation on his axis, which is found to take place once in a little over twenty-five days, argues that the Stars also revolve on their axes.

What is nearest to the Sun?

Next to the Sun, and inside the circle of Mercury, it is claimed by Prof. Watson, as a result of observation of the eclipse of July, 1878, and corroborative of the claims put forth by Leverrier, the French Astronomer, that two small Planets revolve. They can only be seen during total eclipses, if at all, and, if they really exist, the principal one is to be called Vulcan—a name long settled upon.

Describe Mercury.

The first and smallest recognized Planet of the Solar System is called Mercury. Although our Earth is insignificantly small when compared to the large Planets of the System, yet she is a big sister of Mercury, he aspiring to but one-third her size. He has one of the most devious paths of travel marked out for any of the Planets, and is nearly twice as far away from the Sun at one point of his orbit as at another, the near approach being 28,000,000 miles, and the remote withdrawal rising to 48,000,000 miles. Accordingly, unless some peculiar inclination of his poles throws off the heat from his continents when it is the greatest, and garners it when it is the least, the extremes of relative warmth must be vastly diverse. Mercury's year is eighty-seven of our days, and although his yearly motion is more rapid than that of any other Planet, yet his rotary motion does not equal that of the Earth—his day being five minutes longer than ours.

To see Mercury is a very rare occurrence, and it is said that Copernicus, who set the Planets all going by themselves, died without having laid eyes on the coy world, although the most of his life was spent in founding the noble science on the basis of a reason for all things, and although the ancients had known Mercury before history began. If a monster table or floor could be conceived as lifted up under the circles which the Earth and Mercury describe in space, the table, while allowing the Earth to spin and progress around without obstruction, would seriously interfere with Mercury's motions—that Planet being part of the time several degrees above the table, and the other part several degrees below. At just two points, of course, they could come on a level, and, with the Sun in the centre, and the Earth at that very spot, Mercury would come up from under or go down to the table and get directly in line between us and the Sun. This is the only chance for an eclipse of the Sun by Mercury, and as such "eclipses," owing to the smallness of the Planet, fail to eclipse very much, they are merely called transits. The last one happened on the 6th of May, 1878. They are, as may be inferred, very rare, but are useful to Astronomers in measuring the distance of the Sun from the Earth, the problem upon which every other calculation in Astronomy depends for its accuracy, and with every varying solution of which every previous measurement of all things must be modified.

Where is Venus?

Between us and Mercury, when we are in line, is the Planet Venus, apparently the largest Star in the sky, though always journeying down out of the canopy of heaven. The great size of this celestial beauty renders it even visible in the day-time, and enables it to cast a shadow at night. Like Mercury and the Moon, Venus displays changing phases of illumination to the eye—that phenomenon being peculiar to those bodies which at times go nearer to the Sun than does the Earth; but these phases of "first quarter," "half" and "full Venus," do not account for the surprising vicissitudes which characterize the appearance of the Planet; for Venus is really "full" and giving her greatest amount of reflected sunlight, when furthest away.

The real reason is that the Planet is sometimes wihtin 25,000,000 miles of us, when on the same side of the Sun, and that, at other times, she casts her gentle beams from a distance of 160,000,000 miles. Thus, a third of Venus in the hand is always better to us than the whole of her lustre in 160,000,000 miles of bush. Again, to be more explicit, when Venus, as the Morning or Evening Star, shines out the most wonderfully, she is really only one-third lit up, and were it possible to present a full phase this side of the Sun, she would become a much more luminous body than our Moon.

What would the conditions of life be on Venus?

The Planet Venus bears many resemblances to the Earth, and if inhabited, it is probable that the forms of life would continue to bear out the striking physical analogy of the two Planets; although, with the dense atmosphere which surrounds Venus, a human being of our average weight would feel as though he were walking in water. This density would be very unpleasant in many ways. Buildings, for instance, would be found to lack the gravity to stand well, and, if the slightest storm occurred, the safety of every artificial structure would be threatened. Marine life might flourish. Venus, in spinning on her pole, topples over to the considerable extent of seventy-four degrees, which would subject all her zones to the greatest mutations of temperature. The thickness of clouds surrounding the Planet, and her brilliancy when near us, prevent a discovery of the conformation of the globe itself; and as little is known of the land and water of the Planet, as of those of Mercury. The Planet is 68,130,000 miles from the Sun, and the length of her year is two hundred and twenty-four of our days. Her day comes within a few minutes of equaling our own in length. The eclipses of the Sun by Venus (transits), could they be correctly observed, would be of overwhelming importance to Astronomy; but the results which were expected from the transit of 1874, failed to justify the expectations of the World's Astronomers, and there was little inclination to expend time and money on the transit of 1882. The temptation will not be again presented

until an entirely new generation of Star-gazers has arisen, away off in the year 2004. The Planet moves in nearly a true circle. Venus was undoubtedly the second body which the ancients discovered as moving differently from the fixed Stars, the first, of course, having been the Moon.

Where is the Earth?

The Earth upon which we live is the next member of the Solar family. It is called a "spheroid"—which means sphere-like in shape, and is understood to cover a multitude of discrepancies, in the way of twenty-nine miles of flattening at the poles and decided bellyings at the tropics. The law of gravitation established by Sir Isaac Newton (the theory of which was that the apple in falling from the tree was attracted to the Earth, and in turn attracted the Earth—the greater body rising in exact proportion to the superiority of its size) is upheld by many phenomena, the most convincing of which is the action of the

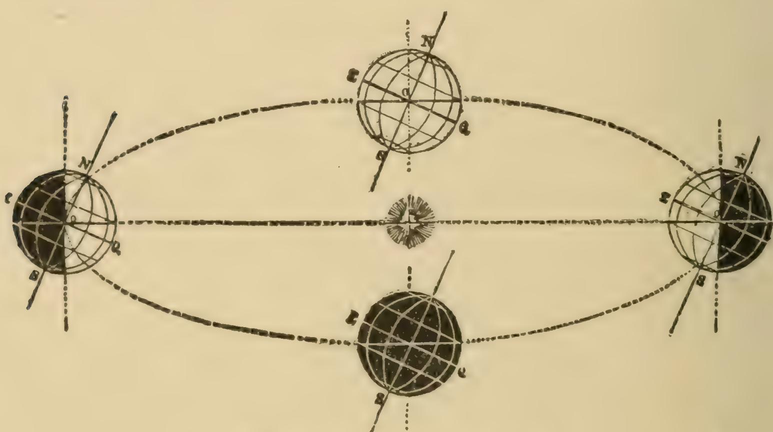


Fig. 172. ORBIT OF THE EARTH.

ocean when passing under the Moon or Sun. The mighty deep really rises up many feet, in obedience to the law which is supposed to rule the Universe. This complex "shipping" of the bulk of the Earth must always remain a great obstacle in the determination of the exact shape of our Planet. The Earth is

91,430,000 miles away from the Sun. Mr. Proctor estimated it as weighing six thousand millions of millions of tons.

What is the Atmosphere?

The Earth is surrounded by a dense atmosphere—not so thick, however, as that of Venus. This atmosphere used to be thought to extend forty miles upward, but recent discoveries showing the inability of light to penetrate a perfect vacuum have hoist our air theoretically to a vastly greater height, and there is a growing tendency to believe that all space itself is filled with something which, if not rarefied air, is nevertheless entitled to some recognition greater than it has hitherto received. Our air is a mixture (not a compound) of Oxygen and Nitrogen. It is invisible, inodorous, insipid, transparent, compressible, elastic and ponderable. Within the interstices of its molecules the still thinner ether of the Universe is theorized as existing.

How do we reckon Time?

Early in history, the year was fixed at three hundred and sixty-five days. As this was nearly six hours too short, the inaccuracy soon betrayed itself in the altered positions of the fixed Stars on any given anniversary. Julius Cæsar added the leap-year day every fourth February. As this made the years over eleven minutes too long, Pope Gregory XIII, at the end of fifteen hundred years, ordered ten days to be left out of 1582—that is, the 1st of September was to count as the 11th of September. To preserve a greater degree of accuracy in the future, he ordered that every year divisible by four was to be a leap-year, unless it was an even hundred, in which case it would have only three hundred and sixty-five days unless divisible by four hundred. Thus 1900, although divisible by four, was not to be considered as a leap-year. The year 2000 will be a leap-year. It is the lot of our Planet to have one of the elliptical lop-sided paths around the Sun, and while the Earth returns to a given point in precisely the time allotted, still the variations meanwhile are quite marked. Thus our clocks, made to go regularly, get far out of the way at certain parts of the year. A clock which will tally with the Sun every 1st of June, will be fifteen minutes slower than the Sun-dial on October 27th, and fifteen minutes faster February 10th.

What makes the Seasons?

The Earth, instead of spinning uprightly, topples over sixty-six degrees and thirty-two minutes. This characteristic of the Earth condemns the poles to experience alternately six months of day and six months of night. As the top of the Earth leans toward the Sun on one side of the path, the Northern part of the World will be lit far over the pole, and the Southern part will be denied light to the exact extent that the Northern pole gets more than its share. Then (as the Earth always leans the same way) when the other side of the path is taken, the situation is reversed. The most brilliant of electrical displays, however, are said to illumine the long nights of the polar regions. During the period of constant light, the Sun travels around the heavens. During Summer, in the Northern half of the Earth, the Planet is in the portion of her path furthest from the Sun; but the fact that the Northern Hemisphere then sits up straight against the Sun, renders his rays highly effective in raising the temperature of our atmosphere, which otherwise would be almost unendurable. The difference in directness more than counteracts the natural effects of greater distance. In Summer, the distance of the Earth may be represented by the figure 61, while the figure 59 expresses the distance in winter. The Earth travels faster in Winter than in Summer, in the same proportion. "Winter" here means Winter in the Northern Hemisphere. We get our most upright position to the Sun in Summer. But the Earth is then in the tip end of her egg-shaped path around the Sun, and the Sun is away off in the further (big) end of the "egg" two-thirds of the distance towards the shell. Now, of course, it takes a long time to go to a long way, and all the time that we in the Northern Hemisphere are tilted up snugly catching the rays of the Sun, and complaining of warm weather, the people in the Southern Hemisphere, say at Cape Horn, are tipped away from the Sun, and their Winter is as long as our Summer. When the Earth gets around to the big end of her orbit, then we are tipped away, and, although closer to the Sun, still experience Winter. But it does not take so long to go a short distance as a long one, and in fact, the Earth goes faster just because it is nearer the Sun—so our Winter is soon over, while the Southern

Hemisphere, tipped up against the Sun when the very nearest, roasts in Summers as unpleasantly hot as the Winters are unpleasantly cold and long. We plainly have the best of the bargain here in the Northern half of the World, and fortunate it is that so much of the land lies to our side of the equator.

Has the Earth other movements?

There is much more snow and ice at the South pole than at the North pole, and the excess of accumulations at the former pole may account for a slight movement (nutation) which the Northern pole makes around a center. The heaviest body or portion of a body is pulled the hardest by whatever attracts it. Ocean currents and winds may greatly ameliorate the weather in some parts of the Southern oceans. The solution of the Earth's motions is always complicated by the fact of her being accompanied by a Satellite. The center of the Earth's motion is not at the center of the Earth, but at a point between the Earth and the Moon, where, if hung in scales, the two orbs would balance each other. So the Moon in revolving around the Earth, also forces the Earth to revolve about their common center. These movements can be easily demonstrated on any ball-room floor, when two people join hands and swing around. If the parties are of the same weight they will revolve equally, but if the lady be much lighter, as frequently happens, she will find herself traveling through the air much more rapidly than her partner, who still describes a small circle in the air with his head. The path of the Earth is called "the Ecliptic" and it is the mutual center of the Earth and Moon which journeys upon this course and not the center of the Earth.

What is inside the Earth?

The Earth, like all the Planets, having evidently been in a high state of heat when thrown from the Sun—if that event ever took place—has cooled down sufficiently to form a solid crust at its surface. The relative thickness of this crust, however, compared with the size of the Planet, does not equal the thickness of an egg-shell, and when the natural conjecture is raised that the mighty mountains of Asia might crush in this weak crust, the answer is returned that no mountain exceeds a height of five

miles and that an ordinary orange has greater inequalities of surface in proportion to its size than has our World. Our mountains are folds in the shrinking crust of the Earth. Upon descending into the Earth the heat rapidly intensifies. At thirty-five miles almost everything is in a state of fusion. At one hundred miles, absolutely nothing has withstood the enormous power of the smothering fires, and platinum and all other of the hardest of earthly substances have been reduced not only to fluids, but even to gases.

What is the Moon?

The Moon, though frequently appearing as large as the Sun, is still only large by reason of her unequaled proximity to us, she being in reality by many times the smallest of the Worlds exposed to casual observation. Her diameter is only a little over one-quarter that of the Earth. She revolves around the Earth in twenty-nine and one-half days on an average, and has slightly increased her speed since the birth of Astronomy. Were the Earth stationary, the Moon would go around quicker, and we should have a new Moon every twenty-seven and one-quarter days; but the Earth is going at the rate of sixty-eight thousand miles an hour, which accounts for the additional two days and a quarter. The Moon, so far as Astronomers know—and they know more concerning her than of any other celestial body—passed the present condition of the Earth ages ago. To an observer of the slow "processes of the Suns" it would seem that a thousand or a million years were very much the same thing; there is no criterion for human criticism other than senses, which are easily deceived even in matters of the most trifling nature in everyday life.

What were Mr. Procter's conclusions?

When the great balls of chaos which are now the Earth and Moon were, in the stupendous phrase of Milton, "hurled headlong flaming through the ethereal sky with hideous ruin and combustion," the heat acquired by the larger body would be great in proportion to its size. The mass of vapor which was to form the Moon at a later period, would not pass through space with the friction which the Earth would encounter. These

bodies would then start in their paths as members of the Solar System with unequal intensities of heat. But, even if they were both of the same heat, the smaller would part with its heat the more rapidly, because the volume or contents of the larger ball would exceed the volume of the smaller ball in a greater degree than the surface of the larger ball would exceed the surface of the smaller. Suppose the big ball have a diameter twice as long as the same line run through the little ball, its surface would then be four times as great as that of the smaller ball, but its contents would then be eight times as great. Therefore, if the heat were of the same degree in each, the larger ball would lose at the rate of four times the loss of the smaller, but would have eight times as much to lose. It is thought the Moon can be seen closely enough in the great telescopes to detect volcanic action if it existed in greater external display than on the Earth, and therefore it is thought there is no such commotion there. So, considering the advantages possessed by the Moon in cooling off, and the lesser intensity of the heat which she would naturally have acquired in her original propulsion, Mr. Proctor, the Astronomer referred to, believed that the Earth would not arrive at the present state of the Moon for the interval of one billion, five hundred million years, and that is, mind you, upon the theory that they both were propelled at the same time, but one happened to be smaller than the other. The Moon seems to have no atmosphere at all. There appears to be nothing of a fluid character left on its surface. Chasms appear in its crust, showing that it is shrinking as its inside cools, and that the crust has to fold. A kettle of mush, when boiling and quite thick, throws up craters which leave its surface presenting nearly the same aspect as that of the Moon when seen through a good telescope. Mr. Proctor spoke of the curious idea, that perhaps these craters or "roly-boly-holes" were made when the Moon was soft, by the fall of Meteors overcome by the attraction of the Moon.

What are the Moon's temperatures?

The Moon has a rotary or spinning motion on its poles, and, strangely enough, this motion is exactly twenty-nine and a half days in turning the Moon once. This leaves the face of the

Moon as we see it, never varying at all—the other side being entirely unknown to us, and never having been inspected by mortal eye. The Moon, therefore, has the longest Solar day of any globe this side of Uranus. Portions of the Earth have but one day and night each year, but the Moon experiences a true day of two weeks, and a night as long, without going to the poles to get them. This extraordinary continuance of sunlight raises the temperature of the Moon beyond anything we endure on Earth, and the long lapse of night effects a change to a point inconceivably below the severest rigors of our Arctic midwinter. It is credibly guessed, by the use of the newest scientific inventions, that the difference in temperature at any one point between "midnight" and "noon" of the Moon's fortnightly day, equals five hundred degrees of centigrade. The centigrade (one hundred degree) thermometer calls the freezing point zero, and the boiling point one hundred degrees above zero. The Fahrenheit zero is thirty-two degrees below the freezing point and two hundred and twelve degrees below the boiling point. The difference in a degree of centigrade and a degree of Fahrenheit is as one hundred to one hundred and eighty, or five to nine. We have then the result that it is nine hundred degrees of Fahrenheit hotter at "noon" on the Moon than it is at "midnight." On the Sea of Aral, in Asia, in Chicago and at Ballarat, Australia, three of the most variable regions on the Earth, the greatest known difference is from one hundred and twenty to one hundred and thirty-two degrees, the higher figure of variation having been recorded in Chicago. At Madras, India, there are only about five degrees of yearly variation on an average, which, however, would place the extremes further than five degrees apart.

Is there life on the Moon?

Of course the feeling which always most urgently animated Astronomers, was to use the greatest of their aids (the telescope) to discover life upon the little Planet above us. Although the use of great glasses has drawn the Moon within two hundred and thirty miles of the human eye, and although an aqueduct, a bridge crossing a chasm, or the domes of a city, could have been discerned had they existed, still not the slightest vestige of

animation has the cold, sterile surface of the Satellite ever vouchsafed to Man, and with later years, the idea just alluded to, that the Moon has survived the period of vegetable and animal life, has taken hold of Astronomers' minds, and has robbed the subject of much of its previous piquancy. It is, too, reasonable to conclude that the Moon, being a smaller body than the Earth, and having turned hard and cold, should have gotten through with all the phenomena of cosmic experience which pertain to life and growth.

Suppose a collision of Earth and Moon took place.

Should the Moon suddenly lose the impetus which forces her along in her complex orbit, and then obey the attraction of the Earth and begin her portion of the direct journey which the two bodies would make ere the collision took place, she would attain a motion before reaching the Earth, which when suddenly converted into heat (as it would be) would turn a whole continent of the Earth into a sea of raging fire.

How would the Earth look from the Moon?

If there were inhabitants on the Moon, they would never see the Earth if they lived on the other side, and the Earth would maintain a certain fixed place in the Moon's heavens, although varying greatly in its illumination. When it was fully lighted, it would look much larger than a cart-wheel. One curious effect in a World without an atmosphere, would be the instantaneous darkness which would envelop the people the moment after sunset—no such thing as twilight being possible.

What of the Moon's motions?

The practical problem of telling where the Moon will be in our heavens at any given time, is perhaps the most difficult one ever attempted by mathematicians. Owing to the imperfect data upon which they are forced to figure, the results are still slightly at variance in different countries. A more correct measurement of the Sun's distance will, one of these days, make a great many obstacles disappear from the rough path of the investigator.

Where is Mars?

Outside of our circle, and at a distance of 139,312,000 miles on an average, is the Planet of Mars, one of the prominent

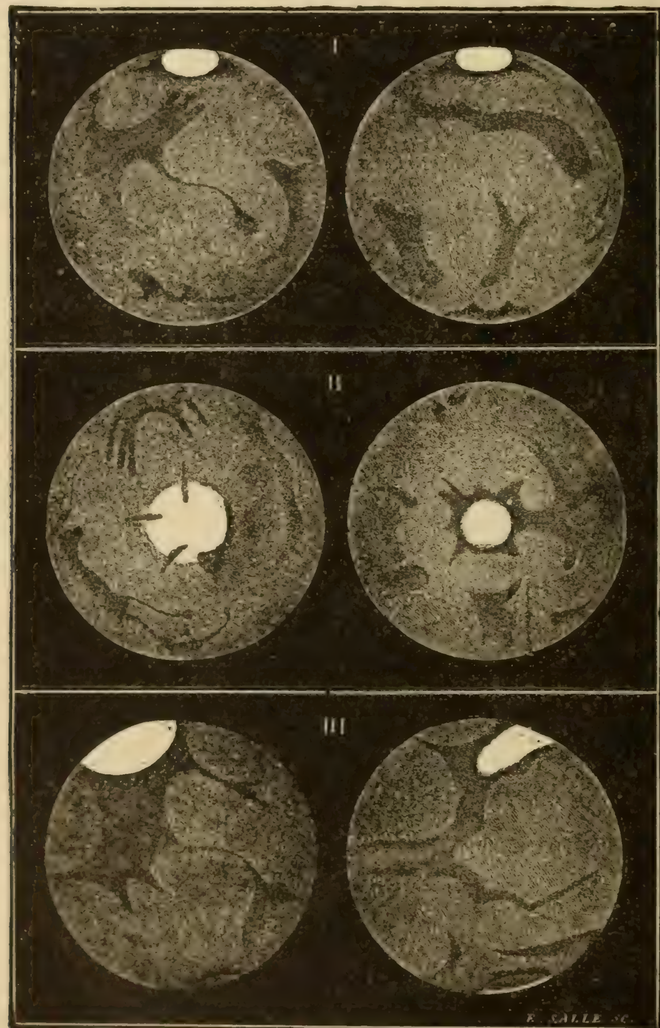


Fig. 178. MARS.

objects in the heavens. Up to this point the Planets, as we have proceeded from the Sun, have gradually grown larger; but this one, although nearly 50,000,000 miles further from the Sun, drops in size one-eighth the bulk of the Earth, being but 4,920 miles in diameter. After the discouraging results of the astronomical exploration of the Moon, men turned their attention to this Planet, the fact of his frequently passing the Earth when he was nearest the Sun, and best lighted up, greatly favoring their attempts. The fruits of whole lifetimes of observation have made us thoroughly acquainted with the contour of that globe, and certainly furnished us with romantic food for speculation. There is the most striking likeness between the Earth and Mars. Continents and oceans are plainly discerned, and the waters have a greenish hue. The continents surround the Planet, however, in belts, so that a railway journey entirely around would be practicable with our inventions. Snow is seen to remain perpetually at one of the poles, now increasing in quantity in winter, and now nearly all melting when the pole tips towards the Sun. Mars' day is twenty-four hours thirty-seven minutes and twenty-three seconds in length. But it must be very cold at Mars, unless the atmosphere, which is dense, is sufficient to modify the natural frigidity. All the oceans, some Astronomers claim, should be frozen over, though that would explode the theory of the polar snow decreasing periodically. The year of Mars is much longer than ours, he making his circuit in nearly six hundred and eighty-seven of our days. He is also erratic in his trip around the Sun, sometimes being 26,000,000 miles nearer the Solar centre than at other times. His distance from our world changes all the way between 48,000,000 miles and 231,-612,000 miles, greatly affecting his appearance as a Star in our skies. The Sun looks, to the inhabitants of Mars, if there be any, only one-third as large as it does to us. They never see Venus or Mercury. The Earth and its Moon, however, give them a beautiful pair of ornaments for their evenings, probably forming two Stars which far outshine all others in their heavens the two constantly varying in distance from each other, and yet never separating further apart than the Sun's disk appears in width to us. The Astronomers have mapped the whole of Mars,

drawing every continent, strait, ocean, bay and peninsula. In 1893, the theory was advanced by Winslow, of Copenhagen, that Asteroids, in striking Mars, have ploughed out the canals.

Has Mars any Moons?

One of the strangest things to be recorded concerning the progress of Astronomical science is the fact that, during the long ages since the time of Galileo, notwithstanding the exertion of the utmost patience and vigilance in the search, Mars, until the year 1877, was declared to be unattended by any Satellite. In that year an American Astronomer really astonished the scientific world with the announcement that two little Moons travel in company with the War Star. These two Satellites of Mars necessarily possess the noticeable characteristic of having the smallest orbits known to man. They have been seen since 1877.

What was Bode's Law?

Outside of Mars travel the Planetoids, called perhaps more frequently, Asteroids, the "oid" meaning "shape" or "form" in its Greek clothes, and the "aster" being taken from the Greek word for "star." In 1778, Professor Bode, of Berlin, published a conjecture which has since attracted so much attention as to be called Bode's Law. He claimed to have a mathematical guide for the arrangement of the Planets of the Solar System, and prophesied the final discovery of outside Planets which would continue to carry out the conditions of his rule. He claimed that if the numbers 0, 3, 6, 12, 24, 48, 96, each of which, after the second, is twice as great as its predecessor, were placed in a row, we could, by adding four to each one, get the ratios of distances of the Planets from the Sun. But there was a hole in his theory, though the discovery of a Planet exactly in that hole would set everything right. Thus, with Bode's law, we had the following proportionate distances from the Sun. The real proportions are indicated below the names:

4	7	10	16	28	52	100	196
Mercury.	Venus.	Earth.	Mars.	——	Jupiter.	Saturn.	Uranus.
3.9	7.2	10	15		52	95	192

Prof. Bode urged Astronomers to renewed efforts to discover a Planet in the place occupied by 28, which would complete the scheme and furnish a beautiful mathematical expression of the symmetry of the Solar System. Thus, the Earth is marked 10, while Mercury is marked 4. We multiply 10 sufficiently to get our distance, say nine times, calling it millions—ninety millions, or to be closer, 9¼ times—92,500,000; then by multiplying Mercury's figure the same way, we get 38,250,000 miles, at which distance Mercury frequently travels in his circuit. So with all the other figures.

How were the Asteroids found?

Soon after this, six Astronomers divided the heavens among them systematically, and, in a short time, the Italian Piazza, found a "Star" which moved, and therefore was a Planet. Its position corresponded with Bode's law. The Solar System being entirely harmonized by this discovery, the astronomical world settled back in satisfaction, and was soon startled beyond all precedent by Olbers' discovery of a second planet revolving in nearly the same path occupied by Ceres, the first one. This was a complete anomaly in the Solar System, and perplexed the scientists. Finally, after profound thought, the theory was formulated that these sister-Planets might have once formed a single World, and, if so, it was probable that other pieces might have been projected into space at the time of the great explosion or disintegration. This again set the Astronomers actively at work, and the list of these little strangers has since been swelled to over one hundred and sixty, discovered by thirty-three Star-hunters, and an American, Professor Watson, formerly of Michigan University, in the town of Ann Arbor, having found no less than twenty-seven up to 1879. These Asteroids were all very small, the two largest measuring only two hundred and twenty-eight miles in diameter, and many of them being less than fifty miles in greatest thickness. During the next two decades, the number was enormously increased by the photographic process. In 1893, for instance, Charlois, of Nice, and Wolf, of Heidelberg, located forty new Asteroids. Their Orbits present the most irregular outlines encountered in the Solar Planetary System.

The inclination of their orbits also—that is, the going above and below a table on which the earth would "play" in its circlings around the Sun, as explained in the case of Mercury, is marked. Venus goes nine degrees above and below the table, whereas, if she reached ninety, she would go around a table that was set over the first table on its side, with its top vertical to the top of the first table, transferring the supposed Sun also to the center of the second table-top. Now, the height reached by some of the Asteroids is forty-two degrees, so the reader may judge of the difference between our ecliptic and their orbits. They are not believed to be spherical in shape, the light which they reflect being sometimes twice as great as at other times. The summer of the northern hemisphere of Ceres is twice as long as the summer of the southern hemisphere, which is owing to the excessive leaning-over of the Asteroid, like a top nearly "run down," together with the great eccentricity of its path. The nearest of the Asteroids is about 201,000,000 miles from the Sun on an average, and the furthest 313,000,000 miles. The liberty they take with these average distances, however, would give one very little idea of their position at any given time. There is one portion of each of their orbits which seems to furnish a point where they might all have started, supposing the explosion of the Planet which might have formed them. The Asteroids which approach this spot the most coyly, might have been projected the furthest by the shock of the fulmination, and readily accepted the devious orbit thus forced upon them. All the orbits are interlaced, and one ring would lift all the rings. They were at first named after the goddesses of mythology—Ceres, Vesta, Pallas, Juno, etc.—but are designated among Astronomers by the figure expressing the order of their discovery inclosed in a circle, thus, Ceres (2.) The unaided eye has rested upon only three of them, their precise location being necessarily fixed upon first, and the Asteroids presenting only the faintest specks of light. The most powerful telescope has never succeeded in giving them disks to the eye, as the other Planets present when observed with an instrument. They must be, as the celebrated Olbers guessed, the fragments of a broken World, and the smallness of their combined influence in turning other Planets

out of their circles, would perhaps indicate that the original Planet was not a very important affair—scarcely as large as Mars. Observations made upon Victoria (No. 12), in 1889, were computed finally in 1893, and the distance of the Sun from our Earth was placed at 92,800,000 miles. The mass of the Moon was thus reduced one per cent., and all other accepted measures disturbed.

Where is Jupiter?

The Planets we have previously spoken of have all hardened down into solid bodies, cold and opaque at their surfaces. Now, beyond the Asteroid family, at a distance of 475,692,000 miles from the Sun, on an average, swings a ball of igneous matter, still all aflame, and able to cast rays of light of its own were the Sun to be taken away. This Planet is the largest in the Solar System, being equal to over 1,200 balls like the Earth melted into one. His diameter is 85,390 miles, but his weight, he being so greatly heated, does not of course, equal that of the Earth, all things being equal. While he is 1,200 times as big as the Earth, he is only three hundred times as heavy. He travels more slowly than the Earth, as do all Planets outside of her orbit, and completes his year in something less than twelve of ours. Jupiter's motion on his axis, however, is extraordinarily swift, the whole rotation of his bulk being completed in ten of our hours. Eight Moons revolve around the Planet, four of them as large as our Satellite, and the heavens of Jupiter must be a rare sight indeed. About 9,000 Solar and lunar eclipses vary the celestial panorama.

What did Jupiter's little Eclipses teach us?

It was through the eclipses of Jupiter's Moons that the speed with which light travels was first ascertained. These eclipses were found to vary from the time set for them. In the period when the Earth and Jupiter traveled nearest each other, the eclipses happened eight minutes too soon, and when the Earth was exactly opposite, or furthest from Jupiter, the same phenomena were just eight minutes too late. This gave the learned men reason to hope they could finally account for the discrepancy, and Von Romer at length proclaimed that the

difference was owing to the fact that the light had to travel 180,000,000 miles further to reach us in one place than in another, and that, therefore, it must be true that light would travel that vast distance in sixteen minutes. This theory has survived the most careful investigation. The Moons go around Jupiter, supposing him to be stationary, in one and three-quarters, three and one-half, seven and sixteen, and three-quarters days respectively. One of them is shaped like a watch. Another is egg-shaped. As in our case, Jupiter is traveling, and some time must therefore, in like manner, be added to each of these periods, though not so much as is added to our Moon's proper time, for his speed is less than our own. Jupiter's day is measured by watching and noting the time of re-appearance of certain spots on his disk, as is done with the Sun.

What is the appearance of Jupiter's disk?

Jupiter stands nearly straight on his poles, his inclination being only three degrees. This should exempt him from the vicissitudes of heat and cold to which we are subjected, but his surface presents the appearance of suffering the most violent cyclones. Great belts of flame travel across his disk at a terrific speed, and this far-off World, whose condition should be so very peaceful, seems in reality, to be a sort of celestial dervish, the author of his own woes, in this manner of furious turbulence comparing much more closely with the Sun than with the Earth. The spots and bands seen on his face, exhibit all the eccentricities of Sun-spots, when once it is considered that the heat by which they are created is much less intense. Jupiter presents to the human eye the appearance of a beautiful Star, passing to all parts of the skies, and like Venus, capable of casting a shadow by his own unaided light. He has been known since the dawn of tradition.

Where is Saturn?

As we travel off into outer space, as seen in Bode's law, the distances more than double between each station, and when the Planet Saturn is reached, we are eight hundred and seventy-two millions, one hundred and thirty-five thousand miles away from the Sun. We are now at the confines of fhe Solar System, as

known for thousands of years, and it is little wonder that the ancients were content with a sweep of such majestic proportions. The sister-World which journeys in that cold region, has been the cause of endless speculation for nearly four hundred years. Around the body of the Planet, and evidently moving by itself about the mother-World, is a system of rings one hundred and seventy miles in diameter and forty thousand miles broad, which would leave the inside or the inner ring lifted ninety thousand miles into Saturn's heavens. These rings are so thin, as to be entirely invisible when presented edgewise to a large telescope, and therefore disappear during that portion of his circuit in which such a position is assumed toward the Earth. Their entire thickness has been estimated as low as fifty miles. Saturn is one of the giant Worlds, being seventy-one thousand nine hundred and four miles in diameter, which is a volume three times as large as all the Planets, if Jupiter were excepted. He is seven hundred times as large as the Earth, but a bucketful of Earth would weigh as much as seven or eight bucketfuls of "Saturn," the whole Planet weighing but ninety times as much as our World. The long period of twenty-nine and one-half of our years is required for one of his revolutions around the Sun, but, as is the case with Jupiter, his daily rotation is extraordinarily swift, the whole day being finished in ten and one-half hours, implying a speed at the equator twenty times as great as ours.

What is thought of Saturn's Rings?

The latest guess of our Astronomers is, that the rings of Saturn are composed of minute satellites, traveling with immense velocity, and making a ring much as a burning stick brandished in the air will convey the same false impression. The rings may look at the surface of Saturn, much as our Milky Way looks to us, and the inhabitants of Saturn, if inhabitants can exist in the unmistakable heat of that body, may think as little of their rings as we do of our starry peculiarity (though they also have the Milky Way). The rings are believed by some theorists to be solid enough to cast a shadow on the surface of Saturn. Owing to the igneous condition of Saturn the difficulty of gaining

exact information from incessant study of his phenomena is great, for the observer is not sure that the measurements which he obtains will not be entirely changed by the sudden shifting of gases or clouds upon the Planet's surface. It is the natural result of a study of these great Planets to class them rather with the Sun than with hardened Worlds like ours, and, as it may be that the glorious brightness of the Sun is only the production of an envelope surrounding a dark body, upon which we gaze through a chasm in the covering, so, too, the vast bulks of these outside members of the System may be illusory, and only the disguises of much smaller masses of creation. The Planet, or its atmosphere, is seen to have a flattening at its poles of four thousand miles, which is sufficient to greatly alter it from a spherical form. In the solemn sweep of this winged colossus around the Sun, the whole distance of our puny Planet from its Solar center is absorbed in a variation of his mighty course, as he is sometimes one hundred million miles nearer the luminary which attracts him than at others. The Sun at Saturn has dwindled to the appearance of a Star twice the size of Venus.

Has Saturn any Moons?

Saturn is attended by the large number of nine Moons, one of which, Titan, is a good deal larger than our Moon, and seven of which are a good deal smaller. Owing to a peculiarity of their orbits, they seldom come between the Sun and Saturn, and therefore do not furnish Astronomers with interesting problems and aids to further knowledge, such as are afforded by Jupiter's lunar eclipses. Until telescopes are made ten times more powerful, at least, most of the more familiar observations made in books regarding Saturn will be principally guess-work, but with favorable chances for their ultimate corroboration.

Where is Uranus?

On the 13th of March, 1781, Sir William Herschel discovered another member of the Solar System. Thinking it at first a Comet he so announced it, but further study of its peculiarities, showed it to be a World thirty-three thousand miles in diameter and going around the Earth once in a man's lifetime, if he live eighty-four years. The name of Uranus was finally given to the

waif, after calling it Georgium Sidus (George's Star, after George III) and Herschel. The love of symmetry in the human intellect was too strong to depart from the mythological series of names, and, though the euphonic properties of the word "Herschel" strongly resemble in smoothness the Pagan names, yet the slightest infraction of the custom has not been allowed, and the unsought honor has been taken from Herschel. No spot on Uranus has been seen long enough to give an indication of the length of his day, but it is found that his inclination is so great, that instead of spinning around the Sun, he rolls. Of course, in space, there is no difference between "spinning" and "rolling;" a Planet would theoretically be as likely to do one thing as another, but this is practically the only Planet which departs from the family fashion of spinning on its pole. It is to be understood that Uranus does not roll like a ball, but like a ball with a knitting-needle stuck through it hanging by the needle between two tracks and rolling down the tracks as fast as the knitting-needle revolves on the tracks. The distance of Uranus from the Sun is one billion, seven hundred and fifty-three million, eight hundred and fifty-one thousand miles, and his orbit is so far from circular as to place him nearly two hundred million miles nearer the Sun at one point than at another. The effect of the "rolling" of Uranus would be, did he move in a perfect circle, to give every point on his surface exactly the same kind of weather, take it the year round. He would then get as "hot" at one place on his surface as another, and as cold "here as there." His day, if he have any, lasts forty-two years. But the Sun, at the distance of one thousand seven hundred and fifty-three millions of miles has become only a small Star, looking three hundred and sixty-seven times smaller than he appears to us, so that his heat cannot have any great effect—that is, such as our gross senses would recognize. It is believed that Uranus has four Moons. Astronomers dispute the statement that there are more, though the number has been placed as high as eight. The Moons go around in two, four, eight and thirteen days.

Where is Neptune, and how was this Planet discovered?

We have now come to the very last of the Sun's Satellites that are known. There is no achievement in the history of the

race so flattering to human reason as the discovery of Neptune, the World whose path now forms the limit of the Solar System. Upon the recognized admission of Uranus into the System, Astronomers fell to work in a kind of pleasant excitement to possess themselves of the vast spoils of knowledge which they hoped this acquisition would yield to Astronomy. But, as the Planets are all effected by the "close" passage of another World, this being the reason of their circles getting so greatly misshapen, the scientists were astonished to find Uranus exhibiting this sort of courtesy in a region where no Planet neared him. The awful problem which was presented, seemed to almost warrant the poetical and devotional sentiment that God himself passed by, and the danger to the science of Astronomy was quickly realized. If this perturbation in the course of Uranus could not be satisfactorily explained—if Uranus went out of his way to meet nothing tangible, the whole fabric of the science fell into absurdity, and the theory of gravitation had its plain refutation staring in the face of every observer.

What did the Astronomers do?

Necessity is the mother of invention. Therefore, the Astronomers invented a Planet. There was no chance to find this Planet, if the right spot were not scanned. A bull-frog in the Atlantic Ocean would furnish more seductive game than the search for a speck in space—in space endlessly wide and deep. Two men set themselves to work to get up the right sized Planet—for a small Planet would have done as poorly as none. Paradoxically, after watching the motions of Uranus, they weighed in their balance the unknown World, which was found wanting. Mr. Adams, in England, at the end of his labors, announced where the Planet must be, and its weight. The paper containing these god-like data he, fortunately for his honor and reputation, presented to the Astronomer Royal of England. At the same time the Frenchman, Leverrier, was independently doing the same work. The search was deferred necessarily during a proper mapping of the Stars in the field of exploration, even that most important of operations being still uncompleted. In the year 1846, Leverrier published his statements, his directions for finding the celestial *sine qua*

non, and his estimate of the probable distance and weight of the body. On the 18th of September, 1846, the telescopes of all Europe being fixed on the spot named by Leverrier and Adams, the instrument of Galle, of the Berlin Observatory, reflected to the eager searcher, the hoped-for discovery. A Star moved from Star to Star, a thing which real Stars never do. A World was found, and the sensation the glorious triumph caused in the minds of men capable of appreciating and understanding it, may easily be imagined. The stranger thus added to our company is two billion, seven hundred and forty-six million, two hundred and seventy-one thousand miles from the Sun. No man not an antediluvian in vitality has lived one of Neptune's years, for it is one hundred and sixty-four times as long as ours; he has not completed a great portion of one circle since his discovery. He is found to have one Moon, which, like the Moons of Uranus, goes backward, as compared with the motions of all other planetary bodies. Not much else is known of him. Had the Star-maps possessed by Galle been also at the service of the Astronomer Royal, it is probable (all Englishmen declare) that Adams would have reaped the undivided honor. However, this assertion is disagreeable to most Frenchmen, and much time was unprofitably employed for thirty years, in quarreling over the proportion of honor due to each discoverer.

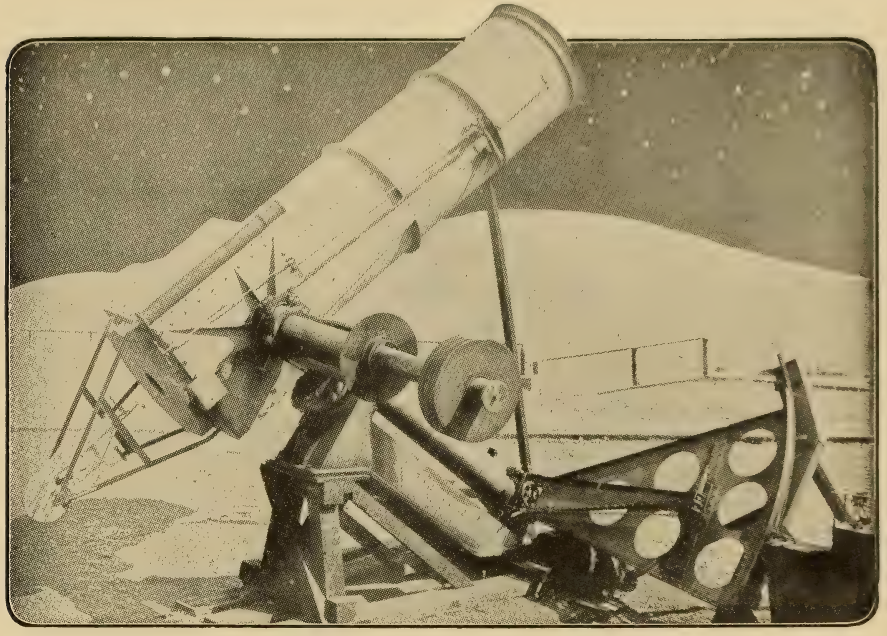
How did Herschel represent the Solar System?

For the purpose of expressing clearly the space evidently allotted to our Sun in the great cheese-like Universe, Sir William Herschel has given the following idea: Suppose that in London, or in some field near the great city, a globe two feet in diameter be taken to represent the Sun, which is eight hundred and fifty-two thousand miles high instead of two feet. Mercury will then be represented by a mustard-seed on a circle of one hundred and sixty-four feet in diameter or eighty-two feet away; Venus by a pea on a circle of two hundred and eighty-four feet in diameter; the Earth by a little larger pea on a circle of four hundred and thirty feet; Mars by a grape-seed on a circle of six hundred and fifty-four feet; the Asteroids by grains of sand in orbits of from one thousand to one thousand and

two hundred feet; Jupiter by an orange in a circle nearly a half mile across (only a quarter of a mile from the globe)· Saturn, by a smaller orange on a circle, four-fifths of a mile· Uranus, by a small plum on a circle of more than a mile and a half, and lastly, Neptune circling in an orbit a little less than three miles in diameter and represented by a large plum. On this scale, the nearest fixed Star would be at San Francisco. It is easy to imagine the room left for other Systems and for our own in the vast stretch represented by the Atlantic Ocean and the wide continent of America, where two feet represent eight hundred and fifty-two thousand miles.

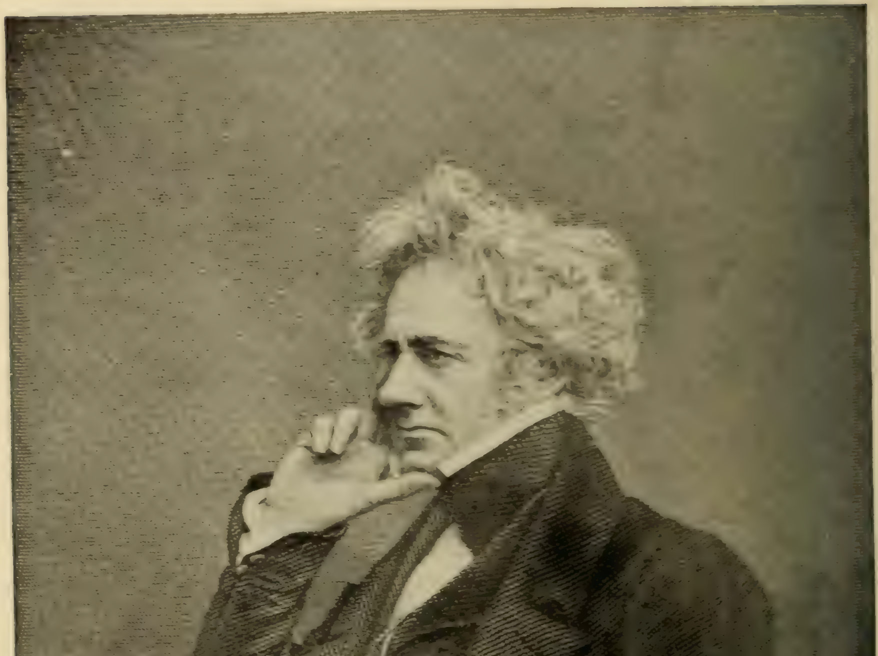
What is the Zodiac?

Now it is plain, that, if so vast an interstice in the great "cheese" be left to the Solar System, then the Stars surrounding the Sun will appear to (although they do not really) inclose it much like a hollow sphere with the Sun on the inside. This we will call the celestial sphere. The Planets spin around the Sun nearly on a level, Venus only going above and below the general plane to any extent. (Astronomers have not taken much notice of the inclination of the Asteroids.) It follows that, if the observer stand on any one of the Planets and take note of the Sun's place among or in front of the Stars (for the Sun is in front of the Stars day and night), the Sun will seem to travel round and round in a certain path, always going in front of a certain set of Stars forming a belt around the concave of Stars. This belt is called the Zodiac. Every portion of the celestial sphere has been mapped off and bunched into one hundred and nine constellations of Stars, and there are twelve of these constellations in the belt called the Zodiac, in front of which the Sun travels. The farmer may get exactly the idea desired to convey, if, while plowing on sloping ground, he lay out a "land" to be plowed around, and somewhere in the center of the "land" or plot, have a sapling or tree growing for shade when the field is seeded for pasture. Now, let this field in which he plows be surrounded, say, by a copse or woods on one side, a clover-field on another side, a neighbor's place on another side, and his own



REFLECTING TELESCOPE AND SPECTOGRAPH.

A new thirty-seven inch reflecting telescope and spectograph for recording the speed with which we are receding from the stars in the southern sky. It is to be used in the mountains of Chili. The rays of the stars are caught by a large mirror inside the instrument, reflected through the small opening in the end of the telescope, and are focused on the spectograph attached to the great instrument. (See page 219.)



SIR JOHN FREDERICK WM. HERSCHEL, F. R. S.

homestead on the other and remaining side. Now, again, with his sapling in the center of the land he commences "plowing round." Let us suppose the sapling to be the Sun and the farmer to be the Earth. As he goes, the sapling seems to pass by the copse, past the meadow, across his neighbor's place, in front of the homestead, and, finally, when a round has been completed, the sapling is in front of the beginning of the copse again. Let us allow that there are only four constellations in our gotten-up Zodiac, and we have exactly the same phenomenon that is every year presented in the heavens—the sapling seemingly passing through the Zodiac, and yet in reality standing still while we do all the traveling.

Speak now with regard to the number of Stars in space.

On a fine night, a person with unimpaired vision is thought to see about three thousand Stars above the seventh magnitude from any one station. Of these, about seven rank in the brightest class and seventy in the second. Stars of the first magnitude are considered to be one hundred times as bright as those of the sixth, although the light of Sirius, the most lustrous Star in the heavens, is generally reckoned to be three hundred and twenty-four times as brilliant as a sixth-class Star. There seems to be something finite and limited in a number which stops at three thousand, and these were all that the early ancients knew to exist. But once point the telescope out, and infinity commands our adoration. Stars of the seventh, eighth, and up to the sixteenth magnitude, become distinctly visible, and their number grows geometrically larger with every improvement in the instrument. With the largest glasses, the original three thousand have swelled to the most exalted powers of human contemplation, and the mind wearies before the task of computing twenty millions of scintillating Suns. There is no evidence yet presented to the reasoning faculties of man to lead him to assign any limit whatever to Creation. There is no more unsatisfactory thought, perhaps, than that induced by so perfect an exposition of Infinite Greatness. To the circumscribed brain of man, when we withdraw all bounds and measures, we depart from its modes of intelligent operation. Man sinks into mingled

astonishment and disappointment. He was searching for gold, but he did not want everything he touched to turn into gold, and leave him to famish in his opulence.

How are celestial distances measured?

It is frequently necessary to find the distance of an object which is inaccessible. For this purpose, man early elaborated the science of angles, called trigonometry, and, if the reader have ever seen a "surveyor's instrument," he has seen just about the device that has served to unfold all the wonders of gigantic distances. If the surveyor find it necessary to ascertain the distance of a tree, he, with great care, levels a strip of ground of considerable length, and as carefully measures it. That measurement is to be one side of a triangle. Of triangles he knows, by previous study, the exact laws. Now, with this "surveying instrument" (called a theodolite), he goes to one end of this straight level line which he has measured, say the right end, facing the tree, and points the telescope at the tree. For great accuracy, the eye-piece of the glass is crossed with hairs, so that even the centre of the telescope can be secured. To avoid description, say the telescope is swung compass-like over a circle, and the circle is marked off like a dial of a clock, into degrees, minutes and seconds, the difference being that, instead of twelve degrees as on the dial, there are three hundred and sixty, and they are called degrees, minutes and seconds of arc. Each degree, like every hour on the dial, has sixty minutes, composed in turn of sixty seconds. When the minute hand on a clock has tipped over seven and a half minutes, the space measured on a circle is forty-five degrees of arc, and at a quarter, it is ninety degrees of arc. If, however, the minute hand were to go backward seven and a half minutes, it would be called forty-five degrees all the same, and not three hundred and fifteen degrees, unless distinctly specified. Now, let the surveyor put the front of his telescope (after getting the first and third quarters of the circle, over which it swings exactly above the base-line on the ground) directly upon what would be the figure twelve on the clock. He looks through and finds the tree to the left of him. So, he swings the telescope to the

left of our "figure twelve," the telescope being pivoted on its centre, remember, and finally gets the tree in the centre of the telescope, when it is, say, "five minutes to twelve" (on a clock). He has previously been paying no attention to the circle on which the telescope swings, but now he looks at it, and at once sets down thirty degrees—that is, one corner of what will be a triangle when he is through with it is now an angle, or coming-together of two cross lines, which angle measures thirty degrees, and is the same thing as is seen when the hands of a clock are five minutes to three o'clock, the angle being at the clock-post where the hands meet. This is all he wished to know at that point—simply how much that angle measured. He now goes to the left end of the base line and swings the large end of the telescope on its pivot to the right of the "twelve o'clock" on the circle underneath. He at last stops at "five minutes" after the twelve, and it, of course, registers thirty degrees again, or the same as five minutes after three o'clock. Now he has two lines starting from a base-line and gradually approaching each other. The law of their meeting is as fixed as the laws of the Medes and Persians. He knows the inclination at which these imaginary lines started, and that when they meet they will meet at the tree. But that is enough. He does his figuring, and the exact distance of the tree is ascertained, and it is more accurate than any common measurement of distance would be if manually accomplished. Now, what should have occurred to man sooner after pointing his telescope at the tree, than to try it on the Moon? He draws his base line, and he feels that he ought to have a long one, so he makes it a mile long. If the Moon be forty miles off, he will still have quite a respectable end to his triangle. It will not be worse than the angle in the hour and minute hands on the big town clock at a minute of noon. He puts his telescope, as a preliminary measure, on the "twelve o'clock," calculating to move it either way it may be necessary. But he is disturbed a little to find it points exactly at the Moon, without any turning. He hurries to the other end of the base line, and finds the same state of affairs; his two angles which he hoped to get, measure zero; and he cannot reckon, for his lines going to the Moon are straight, and must be parallel, or never meet.

What is Parallax?

Now it is time to go back to the field where the farmer was plowing a short time ago. Let us suppose the farmer to take his son with him. They stand on the side opposite the strip of land which borders one side of the field. The sapling stands between them and the woods. The farmer leaves his son at the plow-handles and walks backward in the furrow twenty feet. He looks at the sapling in the centre of the field, and concludes that it is directly in front of a beech tree in the woods. He asks his son about it, but his son thinks it is in front of a sycamore tree, about twenty feet to the left of the beech tree. Now this difference is called the parallax of the sapling. The surveyor would come with his instrument, and with the base line of twenty feet get an angle at each end, form a triangle in his mind, and figure the distance of the sapling in almost no time at all. Then this must be the trouble with the man looking at the moon. He cannot obtain a parallax. What is the matter? It must be that the moon is more than forty miles away. The poor surveyor then wastes his time in getting longer base lines, until he is compelled to admit that the Moon must be very far off, for his base lines ten miles long only make him straight lines out toward the Moon, the fair Queen of Night being in the same place from each end. We have now entered this subject of triangles far enough to say that the triangle we have made is always to be split in two, lengthwise, making two right-angled triangles, so that only half the base line is the base. The squares of the two shorter sides of the right-angled triangle are equal to the squares of the longest side (or hypothenuse).

How do the Astronomers get a base-line long enough for the base of a right-angled triangle?

Their instruments are not called theodolites, but they might as well be. The principle is there. They have accurate time-pieces and have the heavens mapped off, like the Earth, into latitude and longitude. On a certain night, at a certain moment, two Astronomers, one in one city and one in another, thousands of miles off, "spot" the exact latitude and longitude of the Moon. These Astronomers know their distance from the centre

of the Earth. They know their distance in miles apart on the surface. They make a base-line out of a semi-diameter of the Earth. With such a base-line, the Moon easily changes in position. The instrument gives a good angle at one end, the angle is noted, and, Eureka! the distance of the Moon is measured as easily as that of the tree. Now it must be seen that, in the case of the tree, the man had a sure thing, because he really measured the base-line; but the measurements of the Astronomer depend upon many other observations, all going to modify his precedure. The diameter of the World depends on its distance from the Sun, etc. If it be one million miles nearer than it was supposed to be fifty years ago (as it is), it weighs so many million tons more, and it is so much larger; yet it is fair to believe that the heavenly measures are, even in their present imperfect condition, far more reliable than would be those of any set of chain-measures, were such undertakings possible. The angle of the instrument when pointed to the Moon, with half the thickness of the Earth for a base-line, is almost a degree. That is, if we placed two single-handed dials side by side and pointed the hand of the right dial at ten seconds of noon, and the hand of the left one ten seconds after noon, as could be done if the dials were large enough to admit of the division of the minutes on the dial into six parts, and if we supposed the two dial-posts to be eight thousand miles apart, the hands, if continued, out into space, would come together at the Moon, or at something over two hundred and thirty thousand miles away. Here we have the *double* right angle, and used only *one* right angle for the computation. The astronomical base-line is always to be a semi-diameter, or a radius of a circle. But even this base-line, long as it is, is only useful in measuring the Moon and Mars (when nearest), although the parallax of Mars is a point in other triangles by which one may secure the knowledge of other Planetary distances. The Sun's Parallax, or the angle obtained by a base-line four thousand miles long, is only eight seconds of a circle of three hundred and sixty degrees. His Parallax is more easily perceived when Venus and Mercury cross his disk.

Now for the Parallax of the Stars.

Having made the Sun, Moon and Planets jog over a little by obtaining a long base-line, we begin on the Stars; but, in attempting this with a base-line only four thousand miles long, we are just as ingenious as was the surveyor when he began on the Moon. And now come the careful operations which take Astronomy beyond the realm of untechnical talk. The metal circles measuring the hoped-for angle must be "compensated," or made like a fine balance-wheel in a watch, so as not to swell or shrink in changes of weather; the quickness of personal faculties and observation, the sharpness of vision, the heat of the blood, all known as the "personal error," must be known; the observatory must be solidly built from a deep foundation, to avoid the heaving of the frost; the aberration of light must be deducted; the notation or nodding of the Earth must be accounted for, and the astronomical chronometers used must have the smallest possible error, for perfection is impossible. With such reverential exactitude as no priest ever attained does the Astronomer proceed in his offices. The stronghold of incredulity may be greatly shaken by an apprisal of the circumspection with which reason accepts the credentials of truth. Now the observer begins the magnificent undertaking of making his base-line from the center of the Sun instead of the Earth. Getting his angles to the Sun's center from opposite sides of the Earth's orbit, one observation being taken in June and another in December, he gets a semi-diameter of our orbit, 92,800,000 miles long, as his base-line, and proceeds to search for Stars which will give angles. When the two Astronomers took observations of the Moon, they were after geocentric (center of the earth) parallax; now the one Astronomer is in search of heliocentric (center of the Sun) parallax. With his instruments arranged and his mighty base-line established, he proceeds at one end of the line (that is, say, in June) to note the spots in which one hundred Stars are located, the fine silk lines in the eye-piece of his telescope making the operation very exact. Then, at the other end of his line, in a month when the Earth has swung round sufficiently to get three points in all—(1) the angle of the center

of the Sun, (2) the first position of the Earth, and (3) the second position—he again inspects the same Stars. But alas! many of them have not stirred. Upon most of them the instrument points straight out, though angles far beyond the sight of man would be detected by the instrument. However, as if to give man a little hope, a few Stars have shown a small parallax. A double Star in the Southern Hemisphere called Alpha Centauri has indicated the greatest displacement, and must therefore be the nearest Star. The angle running into space toward this double Star was found to deflect almost a second of arc. Now, a second of difference showed that the two lines running into space would come together at two hundred and sixty thousand times the length of the base-line—two hundred and sixty thousand times the distance from the Earth to the Sun (ninety-two million three hundred thousand miles as then measured) or nineteen trillion, thirteen billion, eight hundred million miles away—over nineteen trillion, or nineteen millions of millions of miles, a space through which light, traveling two hundred thousand miles a second, must spend three and one-half years in its passage to us. This then is the nearest fellow of our Solar Master. The great Star Sirius, which is in the southern heavens during winter, moves fifteen hundredths of a second of arc, as viewed from each end of the Astronomer's base-line, and the triangle formed in this manner is six times as long as that running to Alpha Centauri, or one hundred and fourteen trillion of miles. This Star is thought to exceed the Sun in size three hundred and twenty-four times. It is believed that the average distance of a Star of the sixth magnitude is seven million six hundred thousand times ninety-two million three hundred thousand miles, which would require one hundred and twenty years for the passage of light. The Stars made visible by the great telescope are believed to be so far off that light would be fourteen thousand years in getting from them to the Earth. The Astronomer's measuring rod is a delicate affair. Should he measure a dot more than were right, though the dot be but the five-thousandth of an inch (the thickness of a silken fibre), the fruitful seed of error would be sown in fertile soil. There is nothing more thoroughly calculated to

magnify a mistake, than a line started into space at a false angle. A miscalculation of the thickness of a silken fibre at the beginning, becomes a discrepancy of seventy feet at the other end of the Earth, a blunder of three hundred and sixteen miles when the line arrives at the Sun, and when the nearest fixed Star is approached, the line is sixty-five million two hundred thousand miles out of the way. An angle of a second is a subtle thing, and is utterly invisible to the unassisted eye, unless the circle be made very large. For instance, a pair of compasses eight miles long would let a base ball of a diameter of two and one-half inches between its legs at the points, and the opening would be a second in width. It may be imagined how long the compasses would have to be before a World three hundred and twenty-four times as large as our Sun could get in, especially if the compasses were pushed five-sixths further shut. No accurate measure of the size of any fixed Star has ever yet been possible. When one of the Sun's Planets crosses the field of a telescope, it immediately shows a disk like the Moon or Sun. But the Stars twinkle in the telescope just as they do to the eye—in fact, the larger and better the telescope, the smaller the Star becomes. Their differing brilliancy cannot with certainty be attributed to any one of the three causes which would effect it. The greater splendor of one Star might be due to its superior size, its greater proximity, or the unequaled quality of its rays of light, or to all or any two of these reasons. Our notice of the Spectroscope will show the latest conclusions on these points.

What are the Nebulæ?

Astronomy demands even further efforts of the understanding. The earlier discoverers often noticed little misty bunches of matter in their telescopes, giving much cause for discussion, which were named Nebulæ. As the telescopes increased in power, the Nebulæ altered greatly in appearance, and it was found that some of them were really masses of Stars so far off as to offer no specks of light to the small telescopes, but readily resolving before the more penetrating powers of great glasses. Therefore, some Astronomers have considered themselves

justified in the hypothesis that this great cheese of Stars, whose incalculable proportions have just been remarked upon, is only one in a number of similar Universes, some of whose distances are so great as to present with the whole of their incalculable number only a bunch of mist no larger than a man's hand. This theory is now undergoing the unpitying scrutiny of reason and greater knowledge, and may stand; while, again, it may fall.

Does the Sun Move?

Inasmuch as the Sun moves on his axis, like a Planet, it has long been believed that he also must move around some central Sun, carrying his System with him. Thus, we are supposed to be drifting along among the Stars, and the advanced theorists, have placed our motion at one hundred and fifty million miles a year. Either this motion or the motion of the Stars themselves has given many of the Stars a changed position compared with their places on the Star-maps centuries ago. The belief that the whole Solar System of Planets is moving among the Stars has been strengthened by the constellations in one part of the heavens appearing to widen out, and those in the opposite quarter becoming narrower. According to Mr. Proctor, the two Stars in the Big Dipper most distant from each other are traveling eastward, while the five going to complete the inner portion of the Dipper are moving westward.

What are Double Stars?

After the invention of the telescope, it was found that certain Stars previously supposed to be single, were in reality double, triple, quadruple and even quintuple. The number of these is proven to be about six thousand. The Polar Star is one of the double ones. These Stars are found to revolve around each other, and, in the case of the double Stars, this statement is proved by the fact that they separate, which might easily be the effect caused by such revolution, if seen from the Earth. The nearest Star, Alpha Centauri, was found, long after the name was given to it, to be one of this class of Stellar Systems. These Stars assume a double and triple aspect only under the telescope, and are too

close together to permit their peculiarity to be detected by the eye.

How are the separate Stars distinguished?

In speaking of Alpha Centauri, the statement is made useful that, in the infancy of Astronomy, the Greeks and Arabs mapped out the heavens, as they appeared before the naked eye. For convenience of location, they divided the whole sphere of Stars into constellations or groups (for example; Orion), in many cases affixing fanciful names to the group, although in most instances, not the faintest resemblance existed between the namesake and the shape of the constellation. · Then they named the Stars by the letters of the alphabet. Thus, the nearest Star to the Earth is the principal Star in the constellation of the Centaur and therefore Alpha, the first Greek letter. As the telescope has discovered additional Stars in each constellation, it has been necessary, after exhausting the Greek alphabet, to use our own, and after that to begin numbering them with figures, as 61 Cygni—that is, 61 of the Swan.

I know the Big Dipper. Talk to me of that constellation.

Let us go out some clear night. There is a satisfaction in knowing that we see before us an object which has not perceptibly altered since the beginning of history. Without traversing seas and continents, we gaze upon the same spectacle that has claimed the wondering attention of Confucius, Herodotus, Pythagoras, Socrates, Plato, Aristotle, Alexander, Ptolemy, Mithridates, Hannibal, Marius, Julius Cæsar, Cleopatra, Charlemagne, Charles V, Elizabeth, Shakespeare, Frederick, Franklin and Napoleon. All these mighty of the Earth have looked upon this same group of Stars. It is the most prominent in the northern heavens, both on account of the brilliant Suns which go to form it, and from the fact that, of all the distinctively-marked groups, it never sinks beneath the horizon in our latitude. This constellation was called Arktos (Greek for Bear) and Hamexa (Wagon) in the time of Homer, the father of poetry, who lived a thousand years before Christ. There are seventeen Stars visible to the eye in this constellation, astronomically speaking, but to us, and to the World which is gone, seven bright Stars give

to it its shape, six of them forming a dipper, and one of them hanging down a little, giving the handle a crooked appearance, if we are inclined to attach it to the other six (as people always have done). The people of Rome, of course, translated *Arktos* into their word for *Bear*, which was *Ursus*. *Ursa*, therefore, was *She-Bear*. Now, as there was another constellation of the *Bear*, of which the Pole Star was a member, they called the Pole constellation the Lesser Bear (Ursa Minor) and the constellation of the Big Dipper *Ursa Major* the (Greater Bear). As there is a constellation higher in the sky, which is seen much of the year, and is exactly like the Big Dipper in shape on a smaller scale, it has always seemed odd to some people that it should not have received the name of *Ursa Minor* instead of the group which is around the Pole. But the Little Dipper is called the Pleiades, and is spoken of in Job. The Sun passes by the constellation in which it is situated. To come back to the Big Dipper. We go to the north side of the house, and there, spread before us, not very far up the heavens, we have six great Stars, wide apart, but making as perfect a dipper as any one could mark out with six dots. Now, if you do not know where the North Star is, take the two Stars furthest from the handle of the Dipper, and, looking upward from the bottom of the Dipper, about four times as far as the distance from bottom to the top of the Dipper, you run directly to the North Star, the three Stars being in line. The two end Stars in the Dipper are called the Pointers on this account. Around this North Star, all the heavens seemingly revolve, which is owing to the fact that the Earth is spinning around under the Star. The Romans also called the seven bright Stars of the Big Dipper the Septentriones, or the Seven Ploughing Oxen, from which the Latin word Septentrionalis sprang, which, long as it is, means nothing but "north" and has also been adopted into French, Spanish and Italian, with the same meaning. The common names throughout Europe for the Big Dipper, or Ursa Major, are the Plow, Charles' Wain and the Wagon, retaining the old Greek idea. These names are frequently heard here, even among common folk. "Wain" means wagon. Let us begin to name the Stars

of Ursa Major. The first Star is nearest the North Star, at the top of the basin of the Dipper, furthest from where the handle joins. This is Alpha Ursae Majoris in Astronomy (Alpha of Ursa Major) a Star of the first magnitude, (though not so marked by all Astronomers) and furnishes the inexperienced eye with an opportunity to fix the meaning of the term "first magnitude." There are seven Stars of this rank in the northern heavens. Below, forming the outer end of the bottom of the Dipper, is Beta, the second; at the other end of the bottom is Gamma; at the junction of the handle with the basin is Delta; running up the handle the eye rests on Epsilon; and at the end of the handle is Zeta. This Star is closely surrounded by three little Stars, at least one of which every one may see on a winter night. Sharper-eyed people, may, perhaps see the others—they are there, close up. Now, those seemingly little Stars may be as large as Zeta, or they may be nearer, being much smaller and less resplendent with light—no one can tell. Their distance apart sidewise, although the naked eye does not detect a great deal, is probably sufficient to swing a dozen Solar Systems in. Now, dropping obliquely, lies Eta, completing the group, and making the handle of the Dipper crooked. Now draw a line from the North Star to Eta. Continue that line as far again, and you strike the Star Arcturus, another one of the first magnitude, whose distance is unknown, as a base-line ninety-two million three hundred thousand miles long gives no angle, the telescope pointing straight out from each end. Beta and Gamma (the bottom Stars) are of the second magnitude; Delta, Epsilon, Zeta and Eta are of the third magnitude.

What does the North Star teach?

The North Star is not a Star of great brilliancy (third magnitude), but is easily recognizable as a fairly-bright point in a large field where there are no Stars above the fifth magnitude. This Star is Alpha Ursae Minoris, and is *almost* over the North Pole. When the Arctic explorer stands on the North Pole, the North Star will be nearly over his head. It sinks toward the horizon as you go southward. There is no Star so closely to the South Pole which can be seen with the naked eye. Owing to

certain great motions of the Earth's orbit, as it were, the tip of the Earth gradually changes. The reader has noticed the handle of a top describe a small circle as it spinned. The imaginary line called the Pole does the same thing, revolving once in eighteen years around the North Star. This is called nutation. But there is another and vaster motion caused by this nutation, which takes thousands of years for its accomplishment. The laws of attraction complicate the motions of all the heavenly bodies in a remarkable degree. One of these "motions of the orbit" might be fairly illustrated if one took a hoop and swung it around his finger. If he called his finger the Sun, and the furthest portion of the hoop Aphelion (away from the Sun) and the part his finger touched Perihelion (nearest the Sun), then by making the hoop revolve on his finger, he would see that perihelion constantly changed—that is, if there were a blotch of printers' ink at Aphelion, he would, after swinging the hoop sharply twenty or thirty times, find his finger were thoroughly blackened. Of course, if he could hold his finger further across the hoop in the air, and still do the swinging, it would be more exact. Thus, the exact spot in which the Earth is nearest the Sun is constantly changing, and only once in twenty-five thousand eight hundred and sixty-eight years does the Earth occupy the same spot in space when it is at Perihelion. This change is called the Precession of the Equinoxes.

What is the Precession of the Equinoxes?

There is not probably in all Astronomy, an expression so thoroughly formidable to the uninitiated mind. But let us cut up these high-sounding words. We all know what "precede" means, but we rarely see the word changed as we change "succeed"—that is, into precession. If you precede me in going to dinner, it is a precession of individuals. The word "nox" meant "night" among the Romans. The reader can detect the word "equal" in "equi"—so that "equinox" means equal night. But "equinox" is one of those words which, after it has been dissected, is still blinding as ever; so we must still investigate it. Let us take an apple and run a knitting-needle through it. Run the knitting-needle into the rest of the apples in the tureen

which may be supposed to hold them on a winter's night, letting the knitting-needle "stand over" pretty well out of a vertical position. The chances are that it will hold its position and fairly represent the position of the Earth. Now, for convenience, take the lamp in your hand and walk around the apple, which should stand well up from the other apples to get a full light. Suppose you begin while the apple is leaning away from you. Then a portion of the under part of the apple beyond the needle is lighted, and a portion on the front side of the top is dark. As you walk either way round, just a quarter of the whole circumference, you have arrived at a point where your lamp throws light exactly to the knitting-needle both at the top and bottom. As the apple must be supposed to be revolving on the needle, it is plain that each side of the Earth will get the light and darkness in exactly equal proportions, and that the night cannot be any longer than the day. This is an equinox. There is one on the other side of the table also. Now, this illustration has reversed the real operations of the equinox, but, if the reader set his light down and carry the apple in the same position, he can get the exact effect. The poles must point the same way all the time of the revolution around the table. If the orbit of the Earth were a circular crevice cut in your floor, and the knitting-needle, standing in the same leaning position, were pounded out flat and two inches wide, and carried in its polar position around on top of the crevice, there would be but these two equinoxial points where it could slip down into the crevice without straightening up erectly. Of course, it would be supposed that these two points would always be reached "on time," but as there is a certain Star out behind each equinoxial point, it was soon apparent to Astronomers that the days began to, say, "grow long" before the equinoxial point, registered hundreds of years before had been reached. So it was found that the old Earth really lagged. It was as though the farmer plowing around the sapling near noon-time, got unendurably hungry in front of his neighbor's place, instead of on the side nearest home. This would be a precession of stopping-places. Now, if we take and bake this apple into a jelly-like condition, and then, by some means, whirl it on the knitting-needle, we will find that the greatest strain on

the pulpy mass is on the parts of the surface furthest from the needle, or at the equator. It probably will swell there. So it is with the Earth. Although we are not sensible to the whirling motion of the Earth, still the easily-movable portions, such as the seas, aided by the tidal attraction of the Moon, swell out the figure of the Earth at the equator and make it more unwieldly, imparting, by the shifting of such enormous masses on its surface, the wabbling motion of nutation. This motion, and the dead weight of the Moon, cause one grand wabble in twenty-five thousand eight hundred and sixty-eight years, just as a top when going with some velocity, may be seen to have two distinct wabbles, one very small one, where the point is not exactly in the center, and one very large one, where the equator of the top nears the table all round by turns. If the Earth were all platinum and perfectly spherical, the attractions of other bodies would perhaps never, by pulling more at one instant than another have set it going in this manner. But the result of this precession of the equinoxes is that the tip of the Earth is really changed, and the North Pole (in addition to the small circle around whatever Star it may be under) makes a grand twenty-five thousand eight hundred and sixty-eight year circle. That is, suppose the North Pole to stick up out of the Earth and "scrape the sky." It would then be seen to go around the North Star in a small circle once in nineteen years, and afterward, leaving that Star to gradually "scrape" a large circle in the heavens, by turn, recognizing different Stars as North Stars, but finally, after twenty-five thousand eight hundred and sixty-eight years, returning to our North Star. There is a powerful force at work tending to make the Earth rotate (spin) pole over pole instead of in its present manner, and this compromise between the two motions represents the proportionate power of the two agencies, every force in nature being felt and responded to by the object upon which it acts. The force which makes the Earth spin, is so much greater, that the effect of the other force only shows in a small way.

What seems to be the history of our North Stars?

The present North Star, *Alpha Ursae Minoris*, has been drawing near the pole since one hundred and fifty years before

Christ. At that time, Hipparchus, a Greek, measured it as twelve degrees from the true centre of the northern heavens, the pole. From those twelve degrees it has worked up to one and a half degrees, and will go much closer. In the year 2100, it will be twenty-one minutes from the centre. Then it will begin its twelve thousand nine hundred and thirty-four year pilgrimage away from the pole. Two hundred years before Christ, the Star *Beta Ursae Majoris*, which the reader can exactly place, was the North Star. Twenty-one hundred years before that, the Star Alpha in a constellation called the Dragon, was only ten minutes of arc from the pole. Twelve thousand years from now the large Star Vega in the constellation calleo the Lyre will be close enough to be called the North Star.

What has been learned of the Nebulæ?

The Nebulæ present so many different aspects as to render it nearly certain that they vary widely in their constitution. While some of them may be Universes, still others of them are only gaseous clouds, torn by evenly-balanced attractions and prevented from forming a single Star. Others, as seen in the telescope, are found to have a most glorious Sun in their centre, and to much resemble a Chinese fire-wheel when in operation. So long as a few of these bunches of mist can be resolved into something less than a whole Universe, there is hope, the best Astronomers believe, that the Nebular Hypothesis of Universes without End may be overthrown, and man be left to grapple with the simpler problem of Worlds without End.

Why do the Stars twinkle?

It has been supposed that the twinkling of Stars was caused by the interposition of the myriads of opaque Worlds which must accompany the Stars, as the Planets obey the Sun, but it was found by Arago, the French scientist, that the same effect could be, and probably is, secured by the rapid changes of color which a ray of light undergoes in every yard of its long trip to the Earth. The Planets also twinkle.

What is seen in Eclipses?

One of the clearest proofs of the accuracy of Astronomical

statements can be given in the prophecy of the occurrence of any eclipse, that phenomenon being foretold with a truthfulness born of the science of mathematics. So, too, in an eclipse of the Moon can the spherical shape of the Earth be demonstrated, for the Earth's shadow, resting on the Moon, can be seen to be the shadow of a round body. In an eclipse of the Sun, the piling of the lesser World upon the greater, affords a fine view of the "ballishness" of the Moon, enabling the eye to see that it is more than a disk.

What are Meteors?

People were awakened in the night of November 13th, 1832, with the most remarkable visitation that human eye ever beheld. The heavens were actually falling, so far as man could trust his sense of vision. Myriads and myriads of Stars shot in all directions, and there was every reason to persuade the mind that the kingdom of heaven was at hand. The excitement caused in America by that event, and the recurrence of the same phenomenon in the next year, extended to Europe; and a theory was constructed which coincides with all that has happened since in the way of Meteoric showers. Humboldt had witnessed a Meteoric shower in South America, the 13th of November, 1799, and the perfect coincidence of date in the month led Astronomers at once to speculate upon thirty-three years as a possible figure for the true interval between these phenomena, and to look for another shower on the 13th of November, 1866. Interest in this country was very great in 1866, and there was a general disappointment felt by the rising generation in America at the non-re-currence of the spectacle over which their fathers and mothers had often dwelt so enthusiastically. But the display was quite grand in Europe, sufficiently so to satisfy the savants of the correctness of their hypothesis, which is as follows: As the Meteors all seemed to start from one point in the sky, the constellation of the Lion, and as this is one of the twelve constellations of the Zodiac, which has been previously spoken of, it seemed probable that the Earth, as it passed between the Sun and the Lion, struck into a zone of Meteors traveling around the Sun. Of course, the moment the attraction of the

Earth operated from a point near enough to overcome the great attraction of the Sun, the little bodies (some of them not larger than a pin's head) would begin what is to us a descent to the Earth. As they enter the body of air which clothes the Earth, the friction caused by their passage immediately generates heat and fire. Thus, they rapidly burn to nothing. At seventy miles from the surface of the Earth, they first become visible, although they look as far away as a fixed Star. After traveling about thirty miles they are usually totally consumed, and go out much like a sky-rocket. However, a few of them attain a size far beyond that of a pin's head, even reaching proportions really formidable; yet the friction of their movement is so great in our thick air, as to accelerate their combustion in a ratio progressing with their size, and there have been comparatively few instances where they have reached the Earth with much of their substance unconsumed by fire. As these Meteors are most frequently seen in November of every year, and as once in thirty-three years they seem to be enormously multiplied in numbers, it is believed that a ring of these bodies revolves around the Sun; that the ring touches the Earth's circle between the Lion and the Sun, but that the ring is not so large as the Earth's path, and therefore reaches it nowhere else. But, if it were on the same level with the Earth's path (supposing the two paths circled out in a meadow), the circles, being so very large, would be found to be a long time almost parallel, before the inner path would begin to cut away to complete its smaller circle. Therefore, as the showers are seen but for a short time, the two circles must be on different levels. The Earth, say, rolls around on your kitchen table, and (taking one of the little bodies, which is lucky enough to get around without being disturbed) the Meteor spins on a plane or level which you could get by tipping up your table seventeen degrees, which is about as much of a whole circle as the space marked for three minutes of time on a dial. The Earth, therefore, at only one point in her path, runs into this circle thick with little stones. She descends through the ring at a slant, and is soon clear of that ring for a year; for, during the first three months it is far above her, the next six months,

wherever it is, over or under, it is much inside of her path, and in the last three months it is far under her, gradually coming up to another contact. The mathematicians figure that, if the ring make one revolution around the Sun in eleven days less than the Earth's year, then the meeting of the two paths or rings would happen at the thickest part of the ring of Meteors once in thirty-three years, and cause a great shower of fire-balls to be seen on the Earth, while only the ordinary quota of Meteors would be seen at other contacts. There is also a display of these aerolites regularly from the 9th to the 14th of August, which is much more certain to reward the watcher for his vigil, and it is believed that another and thicker ring meets the Earth at another point in her orbit. There are believed to be over one hundred of these rings or systems crossing the path of the Earth.

What is the Meteor, as it falls?

When picked up on the Earth, after its fall, the Meteoric stone is intensely hot, showing the great friction caused by its travel in the air. Iron and nickel are frequently found in the stone, and no Element unknown on the Earth has ever been discovered by these accessions to our Planet. In 1803, a Meteorite traveled over France, creating the utmost sensation, and finally, after nearing the ground in Normandy, exploded with a great detonation, spreading its pieces over a wide extent of country. Over three thousand of these fragments were picked up. Perhaps the most remarkable event of the kind on record in America, was the flight of one of these bodies over the States of Kansas, Iowa, Illinois, Indiana, Ohio and Pennsylvania in the fall of 1875. It was seen first in Kansas, looked as large as the full Moon, and was accompanied by continual sounds of explosion, probably caused by the unequal degrees of heat to which its surface and interior parts were subjected, causing the superficial portions to crack and fly off as the Meteor went along. This brilliant apparition caused much talk at the time. Wednesday night, April 9, 1879, fragments from a Meteor set fire to a house at the corner of South Park Avenue and Twenty-fourth street, in Chicago. About two bushels of the coke-like pieces of this fire-

ball were afterward gathered by the people of the neighborhood. The Meteor burst very near the surface of the Earth, and made a detonation sufficiently forcible to throw people off their feet. The accession of these stones to the bulk of the Earth must have an effect upon her motions, although, on account of the infinite minuteness of the changes so brought about, man must perhaps forever remain in ignorance regarding that effect. Mysteries like the fate of the steamship City of Boston, which sailed to eternity, may have been the results of great Meteors falling upon the doomed vessels, driving them into the sea-depths without leaving so much as a spar to be wafted to the anxious watchers for the lost.

Tell me about the Comets.

These celestial travelers bear a very close resemblance to some of the far-off Nebulæ, except that, when they can be seen at all, they are seen to be moving at an enormous rate of speed. They are called Comets, and have amazed man all his days. Considering the almost inconceivable lightness of these Comets, their velocity is cause for the utmost wonder. All of them move before the Stars in a manner indicating the shape of a portion of their path, and Astronomers, having a sufficient portion of the orbit, soon figure up the rest of it. Where they fail to figure out a Comet's orbit, it is where that portion of it inside or across the Earth's orbit forms no basis to work upon. The path of a Comet leads around the Sun on what is often apparently a parabolic curve—that is, a sudden veering from a straight course, and again returning to a straight course, but in a reverse or backward direction, after going partially around the Sun, much as a long belt goes over two wheels, one at each end—it must not sag—only that one of the wheels is lacking. It stands to reason that this is really the case, and that the Cometary belt or path swells between the wheels or where the wheel is lacking, making what is called an ellipse—a circle pulled out of shape. These long cometary ellipses lead to the Sun from all directions, up, down and sidewise. The Comets come in to the Sun, whirl around and go back, and seem to care no more where they are going than a mad hornet. Now a

Comet will rush at a Planet with the speed of the lightning; but now, again, no sooner does it meet the slightest resistance than its course is altered and it darts on in an entirely new path. As the Comets approach the Sun, they stretch behind them a cloud of vapor which has given them their name, Coma (hair), being the idea brought to the minds of the ancients by the sight of their tails. As they carry their tails in front of them on their outward trip, the phenomenon of the tail could be imagined to be caused by the Sun's light undergoing some change in shining through the ball at the head of the Comet, and the rays, thus changed in color after passing through, being visible afterward in space. If the reader has ever seen the rays of a search-light before its reflector, he has seen a trail of light more luminous than the surrounding atmosphere and always increasing in size. The pictures of a locomotive in motion in the night, express this phenomenon by a glare of rays in front of the headlight. It is probable that most of the Comets go so far into space as to require more time for a round trip than the short epochs of earthly experience can cope with, but it is not probable that any of them travel to other Stars. They are very numerous, from four to five being seen every year through the large telescopes, but their closer approach, so as to be seen with the naked eye, is more rare. If we credit tradition, the Comets sometimes seen in the past have been, in certain instances, of a size totally surpassing those which have been observed by competent Astronomers.

What is our History of Comets?

One hundred and thirty-four years before Christ, a Comet appeared which stretched nearly across the sky, a sight which would certainly inspire no little alarm even now-a-days.

Ten years after this, at the coronation of Mithridates, one of the most obstinate foes of the Roman Empire, a Comet came into the heavens with a head as large as the Sun itself.

Remarkable visitations of this character startled the inhabitants of the Earth in 117, 400, 479 and 531, A. D. The two Comets of 400 and 531, are recorded to have each looked like a sword, and to have reached from zenith to horizon.

In 1066 and 1505 Comets went around the Sun having heads as large as the Moon.

It early became the ambition of learned men to harness these wild chargers of the Universe and tame them to the sturdy law which controls each Solar dependency. During the sixteenth and seventeenth centuries, of course, as the knowledge of men rapidly increased, a record of these Comets and their paths in the sky was carefully preserved, and an Astronomer named Dr. Halley, by observing a great Comet which appeared in 1682, was led to examine the records of preceding Comets to see if his observations were duplicated by the accounts of any of them. Sir Isaac Newton had outlined some movements which gave promise of certain Comets' ultimate return, and Dr. Halley believing that he could observe an elliptical shape in the path of this Comet of 1682, and finding that its movements agreed with those of 1531 and 1607, confidently predicted that the three visitations were made by the same Comet, and that it would complete another revolution in seventy-five and one half years. To the astonishment of both learned and unlearned generally, his prophecy was fulfilled in 1757. Therefore, Halley's Comet was immediately accepted as a member in good standing of the Solar System, and the ordinary mathematical labors were undertaken to perfect a knowledge of its orbit. The result was the fixing of seventy-eight and seventy-eight hundredths years as the average time required for its round trip. But Comets seem to go a good deal like "wild" trains on a railroad, and, as they always get the worst of a collision with a Planet in this end of their journey, their movements must be carefully watched to see if any such thing happen, and allow for the changes it may bring about. When Halley's Comet came back in 1835, it had a good deal of bad luck in getting inside the influence of our Planets, but the effects of those occurrences were so well measured by the Astronomers, that the time when it would go around the sun was predicted within four days of the real date. In 1910, Halley's Comet came again. It is a notable fact that the first cometary ellipse or path reckoned by man is the longest yet explored, and of the Comets positively known to come back, Halley's goes much the furthest. The records, such

as they are, lead man to believe that Halley's Comet was the Comet of 1066; and one which came eleven years before Christ can be traced, trip after trip, down to the present time, agreeing with the time and motions of, and perhaps being this same Halley's Comet.

What did Encke's Comet teach us?

The Comet most talked about, of course, has been that one which has appeared the most frequently, having the smallest orbit to travel in. This is called Encke's Comet, and, strange as it would seem, it escaped thorough recognition as a regular visitor until 1818, although it had appeared every three and one-quarter years. The journeys of this Comet revealed new laws to Astronomy, and exploded the idea which had been tenaciously clung to in prior times, that outside space was mere nothingness. The Comet was found to go around the Sun from three to four hours sooner at every revolution. It was therefore conceived immediately that this Comet, and therefore all celestial bodies, passed through a something that, though not air, was yet something rather than nothing, and so, by friction, really retarded the Comet just that much, and drew it a little nearer the Sun. This theory is strengthened by the belief, now universal, that light will not shine through a vacuum, and that we would not be able to see the Stars were not this same thin medium diffused through space, making light-waves possible. If Halley's Comet "slows up" then every other body must do so in the same proportion, but as these Comets are so light and thin as to let a Star shine through them, the effect of friction would tell on them the first of all.

The Comet of 1770, became mixed up in the four Moons of Jupiter, and although it dodged around and finally emerged from its difficulties with a path greatly changed in direction, still not one of the little Moons was in the least affected by the mishap. Next, this celestial moth "struck" the Earth, but the stroke did not move the terrestrial globe, as would certainly have been the result had the Comet possessed any appreciable density. After Comets got inside the Earth's orbit, they would, if they were not mere "bubbles," give the appearance of Venus

Mercury and the Moon—that is, show off horns and phases—but the sunlight does not operate on their heads. Also, when they go around the Sun, they approach so close as to be heated two thousand times hotter than red hot iron, and no body of real matter would ever retain even fluid form at that temperature. From these proofs it is set down that they must be made of the lightest kinds of gas.

Mention the Recent Comets?

Most adults remember the beautiful Comet of 1858. On the 2d of June, in that year, Dr. Donati, of Florence, Italy, discovered it in his telescope, and it was called Donati's Comet. In September, everybody could see it. It went around the sun within a few weeks after it came in sight, on the 29th of September and on its outward journey, showed a tail vastly elongated. At one time in October, this appendage measured fifty million miles. On the 5th of October, the Comet passed the Star Arcturus (referred to previously), and although its tail was several thousand miles thick, still the star shone much brighter than it would have done in unobstructed air, earlier in the summer, when the atmosphere was not so favorable for the passage of starlight. The Astronomers believe that this Comet will be back in two thousand years.

A hazy Comet, without much tail, appeared in 1861. Although it afforded a small show to people "out West," still, in England it was a great sight, having a tail much the longest seen in modern times, and perfectly straight. The velocity with which it came into the Planetary region of the Solar System, outrivaled that of all previous cometary apparitions, and although it was first seen afar off in the telescope in May, the Earth passed through its tail on the 30th of June, and a phosphorescent glare is said to have been noticed in the atmosphere in the night.

In 1874, Coggia's Comet, as it was called, was seen in our northwestern heavens. This was one of those Comets which throw a large quantity of their elementary gas or matter in front of them, leaving the ball half concealed or beclouded inside, instead of a small Star-like head, as seen in the Comet of 1858. It was a great Comet, and was subjected to a scrunity,

the most scientific bestowed on any of its gender up to that time.

In 1881, there were three visible Comets, and two of them were to be seen at once.

The great Comet of 1882, came up from below the South Pole, and was first seen at Rio Janeiro, Brazil. Its tail extended over half way across the heavens. The head was at the east, low down, in the early morning, and the tail spread straight west, half way between the zenith and the southern horizon. It was the greatest Comet since 1858.

What are Astronomic Measurements?

When the Astronomer measures the distance of the Earth, he does so by the semi-diameter of the Earth, that is, by a line which would reach to the center of the Earth. He calls the distance to the sun so many semi-diameters, but he does not know how long a semi-diameter is nearly so certainly as that so many of them would carry him to the Sun. He knows how much the Earth weighs, but it is only in the same way. It weighs a certain fraction of the weight of the Sun, whatever that may be in pounds or anything else. If he be wrong in any one calculation, all others must be changed accordingly. If the Earth be nearer the Sun than he think, then it weighs more than he supposes. If it weigh more without being nearer, then it is smaller. Once settle the distance of the Sun so that all Astronomers shall agree, and then it will be possible to proceed with other calculations without being in the position of a man who is erecting on jack-screws a house to be forty feet high, without knowing whether the jack-screws are to lift or lower the house in the end.

What is Weight?

The attraction of gravitation called "weight" varies at every differing distance from the center of the predominant attraction. If you had a spring weighing-scale and hooked a pail of water upon it which weighed ten pounds at the foot of a mountain, you would find, if you got to the top of the mountain, that it weighed only, say, nine and one-half pounds, the attraction of the Earth being weakened by distance from its center. Of

course, balances would weigh the same above as below, for the attraction would pull equally on each side, and a "pound weight" would weigh lighter also, thus requiring as much nominal weight to balance the water as would do that same thing down below. So again, if you descend a mine, your spring-scale will weigh things lighter than it would at the surface. This is not theory, but has been practically demonstrated.

How is error guarded against?

The observations of Astronomers, however, are carried on in a manner devised to weed out all mechanical errors alone. An Astronomer makes five hundred separate calculations regarding one subject. Each of these processes may vary a trifle. He adds them all together and divides by the number of calculations, thus "averaging his error" and calling the outcome of the division the desired result. Then some other Astronomer does the same work. If his first set of calculations resemble his associate's closely, he also averages them, not accepting any one calculation, but rather trusting the average. After ten Astronomers have got an average from five hundred calculations, then an average of the ten would be considered as nearly correct as human beings could afford to secure.

Tell me now something of the History of Astronomy?

While Astronomy seems to be the most noble, it has also the distinction of being the most ancient, of all sciences. This is probably owing to the intimate relations which have existed between Astronomy and Religion. Certain it is, however, that while we dignify the early study of Astronomy by the appellation of Science, it was little more than a collation of idle fancies, and an exaggerated and useless record of unusual events, principally cometary appearances. Such seem to have been the data acquired during thousands of years by the Chinese, although their pretensions are much greater. Astronomy was born in Chaldea. There, on the plains surrounding what grew to be the mighty Babylon, the outstretching soul of man grappled with the problems presented to him, and built a solid foundation for the erection of the stately edifice which has now

arisen aloft. The Chaldeans, watching all the eclipses that happened during nineteen hundred years, as they claimed, discovered that eclipses took place after the same manner every eighteen years and ten days, and, without a knowledge of the heavenly motions, and with only this discovery of what is called the Lunar Cycle, they were able to predict these sudden obscurations of the Sun or Moon. Their records have furnished modern Astronomers with most valuable aid in discovering a logical passage for Reason over threatening obstacles to success. By their long table of eclipses, Dr. Halley was afterward enabled to guess, and subsequently to prove, that the Moon's path has narrowed in, and the velocity of her motion around the Earth increased, like Encke's Comet.

What did the Egyptians do?

They had a Sothian Cycle, Sothis being their name for Sirius. They had the Zodiac, first without a Balance in it, the Balance being called the claws of the Scorpion. The history of the Zodiac is still to be written. On this subject, and archæology in general, the great Lenormant stands alone. The Twins are the Brother Enemies that founded all cities. The Bull may be Money. Astrology flourished in Egypt, and the seven Planets (Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn), gave the days to the week, and presided over the twelve months.

Who was Thales?

Six hundred and forty years before Christ, Thales, a Greek philosopher, began the real, authentic history and science of Astronomy. Before that the Greeks had navigated out of sight of shore with the Big Dipper for a guide. Thales taught the Greeks that *Ursa Minor* was less changeable. He believed the Earth to be round. Having little to guide his reason, he joined a great deal of absurdity to the morsels of truth which were granted him, and held that the Earth was the centre of the Universe.

Who was Pythagoras?

One hundred and forty years after Thales came Pythagoras, who professed that the Sun was the centre of things, and that the Morning and Evening Stars were the same Planet.

Who was Nicetas?

One hundred and thirty years afterward, Nicetas of Syracuse taught that the Earth revolved daily on its axis.

What Astronomers lived at Alexandria?

Three hundred years before Christ, the city of Alexandria, in Egypt, had grown to be the intellectual metropolis of the world. Here, accordingly, was honor done to the heavenly science and brilliant discoveries added to the treasury of its truths. Here Trigonometry and Geometry, the handmaidens of Astronomy, were born. The science of angles was immediately resorted to in measurements, and, although the theories formulated at Alexandria were altogether false, and even further from the truth than those of Pythagoras, still they were scientific results of the mistaken senses of man, and would have convinced the guessing Pythagoras of their correctness, had he been alive. They had the merit of overthrowing themselves by their own correctness of detail, thus aiding in the final discovery of the true theory. Here Aristarchus mapped the stars of the Zodiac, so that Hipparchus afterward discovered the precession of the equinoxes. Following Aristarchus came Eratosthenes, who proceeded to cast up the circumference of the Earth on correct principles. Euclid, the father of Geometry, lived at this time.

Who was Hipparchus?

On the Island of Rhodes, Hipparchus, the greatest of ancient seers, pursued his studies, and found out far more concerning the science than can one man out of ten thousand now-a-days, 2,000 years later. With his instruments, he watched the passage of the Sun across the sky, and determined that its motion was faster at one time than at another. He thus became convinced that, if the motion of the Sun were uniform, then the Earth was not in the center of the Sun's path, which would be nearly true if the traveling be credited to the real traveler. He marked and numbered the Earth and Heavens with lines of latitude and longitude, whereby he could describe any spot on the Earth or in the skies, and his determination of the length of the year was very close to the true one. To him belongs the honor of finding the backward movement of the North Pole, which will become

a circular movement when enough thousands of years have flown and which was never accounted for until the coming into the World of Newton, seventeen hundred years afterward. This was the precession of the equinoxes, and, of course, the movement was then transferred to, and believed to take place in, the Stars. Hipparchus mapped one thousand and eighty-one Stars, a vast and magnificent labor. It is, therefore, small wonder that all nations have remembered with admiration the man who, as a sentry holding an outpost of vital importance in the hostile territory of Ignorance and Error, did not parley with the enemy by a wasteful invention of baseless theories, but steadily labored in completing defenses which have never been overthrown.

Who was Ptolemy?

After Hipparchus, at a lapse of two hundred and fifty years, there arose an Astronomer who has probably secured more attention than his real merit has deserved. He was a philosopher, however, of commanding intelligence, and, with the appropriated knowledge of all his predecessors, formulated a theory of the Universe which stood before and beclouded the march of Reason for thirteen hundred years. This theory was the Ptolemaic System, accepted by the Church as the true and only Astronomy, and really agreeing very well with the ruder of the apparent motions of the heavenly bodies. The Earth, according to Ptolemy, was the immovable center of the Universe. Around the Earth in succession, moved the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn and the Star-sphere. It seems from this, that it could be seen at that time that some of the roaming Stars called Planets went beyond the Sun. All these bodies (Ptolemy believed) traveled around the Earth in twenty-four hours. To account for certain irregularities which he observed, he placed the Earth at varying points in the orbits of the bodies which revolved around it, and as criticism soon grew fat on its prey, the scheme was changed so that the Planets were held to move in loops, or little circles on large circles. This theory would account for what we now-a-days see in watching Mars, Jupiter and Saturn; for our rapid motion in front of the fixed Stars, frequently gives an outside Planet, which is also

traveling forward, but at a slower rate of speed, the exact appearance of going backward. Then, when the Earth has gone the length of her short orbit and rapidly draws around the Sun, the Planet further out, with a longer orbit, keeps going ahead. Now, its forward motion can be seen, and, as we swing on the other side, backward ourselves, all our motion goes, seemingly, to hasten the outer Planet's progress, and so it seems to go backward and forward, and stand still, just as it would if it were going around a small circle on its large circle. This is called a *node* or knot. In addition to his System, which was written in a great book called "Almagest," Ptolemy handed down, in a collected form, all that had been known of Astronomy up to his time, and it is to him that we owe our information concerning the advance of the science among the Greeks. The most important discovery by Ptolemy was the slight wabbling of the Moon, called libration.

Who was Geber?

Astronomy now slept for five hundred years, and we next see the Arabs advancing the bounds of the realm of celestial knowledge. Passing the "good old Haroun Alraschid" who loved Astronomy, we come to a prince in Mesopotamia called Albatequi or Mohammed Ben Geber. The most valuable discovery of this observer was, that the perihelion of the Earth must change, which phenomenon has previously been illustrated in swinging the hoop around the finger, and is caused by the wabble of the Earth which we have called the precession of the equinoxes. Geber lived about 850, A. D., and wrote several books, which after being collected and translated, in 1537, into Latin under the title of "The Science of the Stars," by men who had much difficulty in understanding Arabic, not to speak of Astronomy; and after then being put in English by men who knew no Arabic, no Astronomy and "small Latin," are believed in their English form to have given rise to the expressive word "gibberish" in our present vocabulary, as the only term which would convey an adequate impression of the high union of absurdity and vagary attained in Geber's work, as published by the English alchemists.

Who was Ulugh Begh?

In 1433, A. D., Ulugh Begh, a Tartar Prince of profound attainments, perfected an excellent catalogue of fixed Stars, the first for sixteen hundred years, which by its accuracy contributed vastly to the material with which Astronomers operated.

Who was Copernicus?

On the 19th of February, 1473, at Thorn, in Prussia, there was born to the wife of a surveyor a child who was destined to lay out work for the mind of man for much future time. This man, Nicholas Copernicus, after reasoning upon the Ptolemaic System, which had triumphantly stood the brunt of sixteen hundred years of objections, and which had become crystallized into the holy religion of good men, entirely overthrew the whole fabric, and erected a theory upon which time and unparalleled discoveries have placed the crown and the seal of legitimacy. It is upon the Copernican System that all which the preceding pages have aimed to elucidate has been based. The great book which demonstrated the truths of Astronomy, doomed, at a later period, to be declared so heretical by the Church of Rome, was, singularly enough, published by Canon Nicholas Copernicus, an inferior dignitary of that same Church, without awakening the alarm of the most apprehensive of its censors. Copernicus disseminated his views in peace, and died May 22, 1543, after seeing the printed page in his own hands which was so soon to disturb heavenly science even more thoroughly than Martin Luther was then disturbing heavenly belief.

Who was Tycho Brahe?

Another, but less remarkable Astronomer entered the World as the great Copernicus left it. This was Tycho Brahe, a Dane, educated at Copenhagen. This man, by the dilligence with which he pursued the problems presented to his mind, gained great celebrity, and was made the recipient of distinguished favors from the reigning sovereigns of his age. But the favors of princes are not enduring, and Tycho Brahe, when fitted out with magnificent astronomical appanage and opulent income, is soon seen to excite the envy of less meritorious rivals in royal esteem, and with bitterness of heart, to set sail from Denmark for

more hospitable shores, to there almost exactly repeat the painful experience of falling from exalted regard to miserable neglect. Although he rejected the Copernican System, and constructed a scheme which soon was proven fallacious, yet his practical observations were so correct, that he made Kepler's discoveries possible, and has, with all his oddities, won immortal fame. The phenomenon of refraction, by which the Sun or Moon or any body looks so much larger at rising or setting than when overhead, had its first explanation at his hands. A person in spearing a fish, will notice that, when the fish is directly under the boat, the spear goes directly down, to the eye, but the further away the fish may be from the side of the boat, the greater will be the apparent bend in the handle of the spear where it enters the water. It is so with a ray of light. When it is thrust into the atmosphere horizontally, it bends the most, and, as that spreads the rays, and as the eye has nothing to judge by but the ends of the rays as it sees them, the object sending out the rays is greatly magnified. As the object ascends the heavens and spears its rays down upon us, the refraction disappears, and we literally "see straight," barring the aberration of light, another but smaller illusion.

Who was Kepler?

The illustrious Kepler was a pupil of Tycho Brahe, and was destined to overthrow his master's system of the Universe. The pertinacity of Hipparchus, finds in the incredible assiduity of Kepler a superior rival for the admiration of posterity. Indeed, the perseverance which unfolded to Kepler and to mankind the inner mysteries of the Universe, has no equal in the annals of history. Up to this time, the idea of perfect circles in the heavenly motions had never been so much as questioned. Hipparchus had maintained untarnished loyalty to the belief in the circular path of the Sun, by accounting for the irregular motion on the theory that the Earth was out of the center of the true circle which the Sun cut in the heavens. Kepler watched the Planets move from Star to Star in the southern sky of the northern hemisphere, and became convinced that he could finally figure out their true paths. Rejecting the highly-complicated

System of his master, Tycho Brahe at once, and making the Sun the center, he began a most careful scrutiny of the Planet Mars. The node or knot of this outside Planet, gives a peculiar motion as seen from the Earth. At only one point in its circle does it seem to make the small circle, owing to its nearness to our path, while the great Planets Jupiter and Saturn, traveling so far off, go along on their little sub-circles (epicycles) in a very orderly manner, making the backward and forward movements all around their orbits at regular intervals. Beginning and calculating the action of Mars, Kepler found that a circular path was not possible for the journeys of that Planet. Having rejected the true circle, he must make another orbit and then find if the motion of Mars agreed with his new scheme. As each new orbit must be experimented upon until slow-going Mars had proved its falsity, and as the patient investigator was relentlessly condemned to see the ruddy object of his attention move out of the path conceived as the proper one for the large number of nineteen successive times, it may easily be understood that this great test occupied a period of eight years. Had his false theories attained a still nearer step toward, without quite attaining to accuracy, he might have been kept the whole of nineteen years in doubt. The multiplication of circles having proved barren of satisfactory results, Kepler adopted an ellipse as a probable orbit, and taking what was good for Mars to be good for the Earth, upon getting the orbit which a Planet should make under such complex circumstances (the observer being also whirled along on an ellipse) through our heavens, was overjoyed to see his assumed orbit become at every point the real path of the perplexing War-Star.

What was Kepler's First Law?

All Planets move in ellipses, the Sun being at one end of the ellipse. Taking the path of a Planet as the fellœ of an ill-shapen wagon-wheel, let us put the hub considerably nearer one side of the fellœ or tire than the other side, not to speak of the ill-shape which would make us do that a little, anyway. Now, let us put in spokes, so that if the wheel lay in a field and were big, there would be an acre of ground fenced in by each two spokes and

the outside fellœ. It will be seen that, inasmuch as the spokes on one side are much shorter than those on the opposite side, they must be set wider apart to get an acre in between any two of them. The long spokes must then, it follows, be close together and the short ones widely separated.

What was Kepler's Second Law?

The Earth, traveling on the fellœ round the hub, must go from spoke to spoke in equal periods of time, no matter what the distance. Kepler's second law translated, reads: "The velocity of any Planet, at any point in its orbit is such, that the line drawn from it to the Sun must always describe equal spaces in equal times." When the Astronomer speaks of this principle he calls Kepler's second great discovery "the law of the equable description of areas."

What was Kepler's Third Law?

By even greater exertions, and after disappointments more depressing than those which had marked his previous labors, Kepler groped out into the dark to find some mathematical relation between the distances of the Planets from the Sun and their time of revolution. By an odd misfortune, when he was once on the right scent, on account of an error in adding up a column, he obtained a disheartening result, and thus again wandered off into new fields of misadventure. Having long abandoned what seemed a useless attempt, he was one day casually and gloomily scanning an old calculation (the very one with the mistake in it) when his eye fell on the error, and Kepler's Third Law was the result: "The squares of the periodic times of any two Planets bear the same proportion to each other as the cubes of their mean distances." The use of this law was, that it told the distance roughly of any two Planets the moment the time of two and the distance of one was ascertained. The square of a number is that number multiplied by itself. The square of 3 is 3 times 3 or 9. The cube of 3 is 3 times 3 times 3, that is, a double multiplication by the first number. Three times 3 are 9, 3 times 9 are 27. Therefore, to take rough numbers, if we should wish to find (by the Earth) how far off Venus might be from the Sun, we would watch her and find by our

eyes that she is in front of the same Star, after accounting for everything, once every two hundred and twenty-four days. We therefore multiply 224 by 224, and 365 (our year expressed in days) by 365. The difference between these large numbers is then traced, say as 2 to 3. Then our distance from the Sun of ninety-two million miles is multiplied by ninety-two million, and the result again multiplied by ninety-two million. This colossal cube, whatever it may be, is to the unknown cube as 3 to 2, whenever it is found. Suppose (to get at it) the gigantic cube which we would get by multiplying 92,000,000 twice to be 96. Now that 96 is known to be to the unknown as 3 to 2, therefore, one-third larger. So the unknown cube must be sixty-four or two-thirds of ninety-six, and when the cube root of this sixty-four, or the small number (4) which twice multiplied would make 64 is found, then the mathematician has the distance of Venus. In this case, the small number would represent sixty-six million miles, the distance of Venus. These remarkable laws were immediately tried by all Astronomers and found to be true. New worlds were discovered, and the same laws operated with them. One Planet was found to have eight Moons, and the same three laws were set over them and tallied to their motions. By these labors it now became possible to say of any Planet that, on a given moment, it would be in front of say, the constellation Leo in the Zodiac, a thing impossible theretofore.

What of Kepler's Book—" Astronomia Nova?"

This great man grasped as near to the essential law of gravitation, yet undiscovered, as he had to his Third Law, in his earlier quest of it, and, by his belief in the existence of some attractive force between any two Planets, and his clear and certain exposition of that belief in the book which he printed, has given cause for astonishment to every philosopher since his time who has contemplated the ease with which Kepler might have seated himself upon the intellectual throne so soon to be ascended by Sir Isaac Newton. When the book containing the marvelous old man's discoveries was opened to his gaze, he said in his transports of joy: "The die is cast. This book is written to be

read either now or by posterity, I care not which. It may well wait a century for a reader, since God has waited six thousand years for an observer." We must reverence the confidence of this hoary sage, who, possessing the most critical and doubt-raising mind of Earth's living creatures, had, after twenty years of incessant idol-breaking, at last erected a shrine before which his satisfied reason bent in unquestioning fidelity. As had happened to Tycho Brahe, and to many other great hearts, the man of science was not considered so obviously necessary as a costly-caparisoned horse, and the difficulty with which Kepler obtained from the royal funds enough to support him during his ceaseless observations, was sufficient to worry him into his grave. He was buried November 5, 1631, old style, at Ratisbon, for a long time the city in which the Congress of the old German Empire was held.

Who was Galileo?

Contemporary with Kepler lived Galilei Galileo, the inventor of the telescope. The life of this eminent Astronomer must, perhaps, be the most familiar of any of the early seers. By his discovery of the ring-peculiarity of Saturn, the Moons of Jupiter, the spots on the Sun, the phases of Venus and the mountains of the Moon, he became at once famous, much as Edison, in our day, appeared at the top of the ladder before any one knew there was a man climbing. The writings of Galileo on dynamics probably opened the way for Newton to truly debate the relations of motion and force, and those books are among the most important of the great Tuscan's triumphs. He established the laws of equilibrium. He estimated the rotary motion of the Sun surprisingly well, and noted the tilting of the luminary at different angles as the year went by. He espied the *faculæ*, or torches, and discovered the proper motion of the sun-spots. He discovered that the Milky Way was due to the multiplicity of the Stars. He perceived the monthly and daily libration of the Moon. He, as well as Kepler, was close on the field of the theory of Gravitation. He foretold that planets would be found outside of Saturn's orbit, and that men (like Bessel) would measure the approximate distance of the nearest stars. In fact, the

first celestial telescope, inconsiderable as it was, fell into the hands of one of the earth's wisest and greatest men. Galileo discovered that bodies fall faster as they fall, and that a pendulum in swinging, occupies exactly the same time whether swinging either a short or a long distance each side of the center. In his old age woes accumulated on the discoverer's head. His daughter died, he became totally blind, and being prostrated with fever and heart disease, he yielded up his soul January 8, 1642, aged 78 years. He was born the day Michel Angelo died. He died the day Isaac Newton was born.

Who was Napier?

Betwen Kepler and Newton was the discovery by Napier, a Scotchman, of logarithms, which must be defined to those unacquainted with a better meaning, as a system of cut-and-dried figuring whereby the enormous labor of going over sums which have once been done by some other man can be wholly evaded. No Astronomer could live to work out some of his problems it he were forced to do all the adding and multiplying saved by this invention.

Who was Newton?

A knowledge of the greatness of such men as Kepler serves as a logarithm to save words in expressing the grandeur of Newton. The inquiring mind must feel that the lustre of Kepler's glory could be dimmed only before a transcendent flame of genius. The brain-power which was given by the Creator, at a later and bloodier epoch in the world's history, to Napoleon Bonaparte for the torment and affliction of weaker humanity, was, in the case of Newton, munificently bestowed for the advancement of knowledge and the triumph of reason. The fall of an apple in his orchard one day set him to pondering upon the speculation of Kepler, that the earth must move up to the apple. Cogitating upon the falling of bodies toward the Earth, he became convinced that the center of the Earth must be the seat of this attraction, and that, were a hole bored through the Earth and a car made to fit the hole, it would rush to the center of the Earth, then, with the momentum acquired, be

thrown past the center, like a pendulum, and then go up toward the surface on the other side less the retardation of the friction the lessening of bulk and the attraction toward the center. So it would oscillate, until finally, it would rest stationary at the center of the Earth, supported by nothing save equal attractions, and yet not falling out of place. With the discovery of Galileo at his disposal—that bodies keep falling faster and faster as they continue their descent to the Earth—he was convinced that whatever the force of attraction, which he named gravitation might be, it diminished in a regular degree as the object attracted was further separated from the attracting body. In order to convince himself of the existence of a law of attraction between bodies, it was needful to examine two bodies which were falling toward each other. As the Earth was so much larger than any body which could fall to its surface, he built up his theory, reckoned up the attraction which the Earth should exert on the Moon, and then, assuming that the Moon was moving through space propelled in a direct line at the time the attraction of the Earth was brought to bear upon her, he determined to see if the amount which she veered from a straight line in every minute's journey was exactly equal to the distance which the attraction he had settled upon would draw her. First, it was necessary to compute the relative weights of the Earth and the Moon. Next, it was necessary to figure out the advantage the Earth would have over the Moon in an experiment near the surface of the Earth. Then, as the Moon is two hundred and thirty thousand miles away, and as this Moon would travel at such and such a force by the time it got to the Earth, and as it would have traveled faster every mile it fell toward the Earth, he must reckon back in accordance and find with what speed it originally started. This speed would be the superior attraction of the Earth and all bodies in the direction of the Earth over the Moon.

What is a Calculus?

To calculate the exact amount a great body would veer from a straight line was not easy; and the reader will perhaps take an interest in examining one of the mathematical devices which

Newton invented, and which will give an idea of the nature of others which he used to accomplish his purpose: Let us suppose a railroad to run along the borders of farmer Roe's "place" for a mile, and gradually veer away, say to the left. Suppose, also a wagon road to run in a straight line past his farm and that the railroad and the wagon road are close together or cross at his farm. Let us suppose the farmers to reside at intervals of twenty miles for a great distance down this straight wagon road, and by some hocus-pocus, to be able to communicate together very easily, but to be entirely ignorant as to the course of this railroad after it veers from the wagon road at farmer Roe's place. Each farmer, however, is curious to know how far the railroad is from his place. The farmers begin a series of measurements. The farmer nearest Roe's place finds the railroad to run four miles back of his place; the next farmer finds it seven, the next eleven, the next eighteen, the next thirty-one, the next fifty-four, the next ninety-two, the next one hundred and fifty-one, the last taken, two hundred and thirty-eight. Now as each station gets further away from the wagon-road, let us suppose that the farmers set down the figures, to see if they can guess what the distance will be from the next farmer's place. It seems a very puzzling operation:

4 7 11 18 31 54 92 151 238

But there may be a law guiding the increase of these numbers. Let us suppose the railroad to be the path of a Planet, and the wagon road the direction it would have taken but for the attraction of another body at the side of its path. Let us proceed to note the differences between these numbers, and then again the differences between the differences:

Differences from the nine farms	4	7	11	18	31	54	92	151	238
First differences		3	4	7	13	23	38	59	87
Second differences			1	3	6	10	15	21	28
Third differences				2	3	4	5	6	7

Here we have arrived at a demonstration that the railroad is moving off under the guidance of a perfectly-adjusted law. We can now go down to the tenth farmer, twenty miles below and tell him that his third difference is 8; that 8 and 28 make his second difference 36, that 36 and 87 make his first difference 123,

and that 123 and 238 must be his distance from the railroad, or 361 miles. This device is called a calculus of known differences, and is here applied to a case where the real distance of the railroad could be ascertained at enough points to determine that it increased regularly. It is here shown as giving the reader a faint idea of the nature of a calculus, for there are several kinds —differential calculus and integral calculus having rendered the solution of problems in curves possible where no solution could be attained without their aid. Of course, if the railroad were turning a circle, like the Moon, it is easy to see that some farmer down the road would travel ahead forever without coming to the railroad, and that the little calculus here shown would be of no value. The honor of inventing these schemes for getting the exact measure of infinitesimal additions to a certain quantity by inferences drawn from inferences, belongs to two men, and furnished an exact parallel to the remarkable doubling of the discovery of Neptune by Adams and Leverrier. Both Newton and Leibnitz found independently the principle of fixing the amount added at each instant to the force of two unequal bodies moving toward each other, or like problems. This fact is now settled definitely, although there has been as much acrimony engendered concerning the invention of the calculi as afterward was brought forth by the wonderful coincidence in the successful efforts of Adams and Leverrier.

How was the Law of Universal Gravitation found?

The character of the mathematical labor upon which Newton now engaged was almost unprecedented in mathematics, and he was intensely disappointed to find, at the end of his figuring, which had occupied him several years, that, if the Moon were drawn round the Earth by any such attraction, that attraction would have to be about one-sixth greater than the Earth could really exert upon the Moon, according to the hypothesis. Thus was his theory—so harmonious and admirable to the mind—crushed by its own conclusions. Shortly after he had abandoned his problem, a philisopher named Picard, greatly corrected the human knowledge of the diameter of the Earth, and Newton, still tenaciously clinging to his hopes, cast up the amount of the

Earth's attraction on the basis of her altered size, and, as the gleam of truth shot out ahead of the slower progress of his figures, he was so overpowered with the importance of his demonstration, that he fainted, and was compelled to call in a friend to complete the details of the solution. The proof of the truth of his discovery lay in an immediate application of the new law to the Planets, and, thus fortified, the philosopher dared to speak to Dr. Halley, the second Royal Astronomer, who immediately recognized and promulgated the law of Universal Gravitation, as follows: " "Every particle of matter in the Universe attracts every other particle with a force proportional to the quantity of matter contained in each, and decreasing inversely as the squares of their distances." Now, everybody can read and understand the foregoing until we get to the "decreasing inversely," etc. As has been said far back, a pail of water is counted for what it weighs on the ground. At four thousand miles from the surface of the Earth that same pail of water weighs—let us see : It is then eight thousand miles from the pail of water to the centre of the Earth, the pail of water is twice as far away from the center as it was on the ground, and the weight of the pail has "decreased inversely" according to the square of the distance. The distance is two times the distance at the ground; the "square of the distance" is two times two, and the pail's weight has decreased "inversely"—outside-in ; therefore, instead of the pail being four times as heavy, it is four times lighter, or weighs just one-quarter as much up four thousand miles in the air as it did at the surface of the Earth. The same law fails to operate on entering the Earth, because thereupon all the particles of matter "above" the pail of water begin to pull backward, detracting from the pulling power of the whole Earth. So, also, the Moon is sixty times further from the terrestrial centre than the ground; sixty times sixty makes thirty-six hundred, therefore, the Moon is attracted to the Earth only one-thirty-six hundredth as forcibly as it would be at the surface of the Earth. By this law, if we imagined a hypothetical station in space without any weight of its own, and if we ourselves weighed nothing, we could *throw* two apples down into space at any distance apart (they would not fall) and

the two apples would slowly begin to revolve around each other until they finally came together. With this law discovered, Astronomy became perfect. No Planet had any motion that was not influenced by other bodies. The theory of Universal Gravitation, as it is the central and fundamental law of Astronomy and of Nature (being at least half and perhaps the whole of the phenomena of motion), has received the severest examination and the most frequent vindication of all Nature's canons, and a great portion of the labor accomplished by Astronomers since Newton's time has been the completion of all the details and consequencces of his law. It is a cant of our customs and manners to-day, that an exception proves the rule. A single exception to Universal Gravitation would pluck from it every vestige of its authority in the mind of man, and relegate it to the company of the experimental theories which it had supplanted. Newton demonstrated the necessity of a wabble in the motion of the Earth from her moving seas and shifting shape; and the precession of the equinoxes was found to be that wabble. He determined that the orbits of Comets should be reckoned up, and his friend, Dr. Halley, computed a seventy-six year tourist of that kind. He made hundreds of inferior but remarkable discoveries, and finally died on Monday, March 27, 1727, the delight of his species for all time.

What did Halley and Bradley do?

Of Dr. Halley's principal achievement you already know. He also was the first to utilize the transits of the inside Planets for the purpose of ascertaining the distance of the Sun. Succeeding Dr. Halley as Royal Astronomer of England, came Bradley. This justly distinguished scientist was among the first to attempt practically, and with chances of success, the measurement of the Stars. Directing his observations to a certain Star he obtained a parallax, or change of position, by views from different standpoints; but finally, while in quest of a different object, discovered the nineteen-year wabble of the Earth, called nutation, and the aberration of light, which completely dissipated what little parallax he had obtained. The aberration of light is caused by the atmosphere carrying a ray of light along a little before it pierces all the way through to the ground. The atmosphere is

moving rapidly with the Earth. It makes a slight advance while the ray is traveling from the upper portion of the air to the bottom. As happens in refraction, the eye follows the ray up out of the atmosphere, and the Star is jogged over two-thirds of a minute of arc. This must always be accounted for in placing a Star, and the Star reckoned as being where our deluded senses refuse to acknowledge it to be. When the cannon flashes at a distance, we must believe that the report sounds at that moment, although the sound comes to us long after the light. The principle is not the same, but there is a likeness in the illusion. In the case of aberration, the light, swift as it is, cannot dart entirely through our atmosphere until the Earth has moved along a little.

Who was Herschel?

Sir William Herschel, born in Hanover, in 1768, settled at Bath, England, and there added to the possibilities of Astronomy the wonders of the Star-depths, compared with which the motions and laws of the Solar System are but as prefatory matters to introduce the subject and fix the attention of the investigator. In scanning the heavens with the largest telescope which had been perfected at that date, he discovered the Planet Uranus, the Star immediately becoming enlarged in the field of his glass and arresting his gaze. He afterward found the Moons of Uranus, saw the belts of Saturn, and became satisfied that there were several rings around the Planet. Rising above the affairs of the Sun and his progeny, he determined that the whole Solar System is moving toward the constellation Hercules. This is still inculcated as correct doctrine by the greatest of observers. While attracted by the marvels unfolded before his eyes, Herschel discovered that not only were the Stars frequently double and triple, but they were of differing colors and varying intensity. (See Spectroscope).

Who was Piazzi?

Piazzi, the discoverer of the first Asteroid, lived at Palermo, Italy, and was born in 1746. He completed a catalogue of six thousand seven hundred and forty-eight Stars, a monument

of devotion to his science, and the fountain of unalloyed admiration among all the Astronomers of his age.

Speak of the French Mathematicians.

The same generation produced three of the most remarkable figurers the world has ever seen—Clairaut, D'Alembert and Euler. To them was the labor apportioned to set a Solar System going and control its innumerable motions by the simple law Newton had left to the world. This triumph of mathematics—although it put Gravitation to the very rack, so to speak, and for a time, by an error which all three of these great scholars fell into, appeared to place Newton back among the guessers who had guessed wrong—finally crowned the Newtonian Ordinance of the Heavens with everlasting dignity, and confirmed it as the most important effort of human genius.

Who was LaPlace?

His name is principally connected with the Nebular Hypothesis. Stars and solar systems, by that hypothesis, are held to be the gathering and compression of vast areas of whorling matter. He was the author of the celebrated astronomical cyclopedia named "La Mécanique Céleste." His great contemporary was LaGrange.

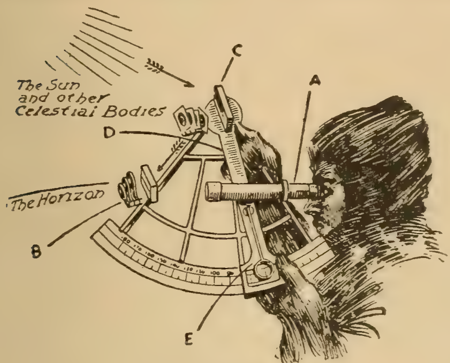
What of Hadley and Godfrey?

They may have really owed much of their fame to Newton, for he seems to have been the originator of the idea of the hand sextant, though the scientific societies accorded the honor of the practical invention equally to Hadley and Godfrey. This little instrument (although itself lately improved upon) has long been a "lion" on shipboard, and North Pole explorers have added to the public curiosity regarding it.

Speaking of North Pole Explorers, how could Peary know when he discovered the Pole?

Of the pole itself, not even the sextant is needed to locate it. Professor Edwin B. Frost (Yerkes) explains that, on a clear day, with the "Nautical Almanac" at hand, say on April 21, 1909, Peary discovered the Pole April 6, Peary would need only a rod set vertically fifty inches high, and a measuring tape. The

altitude of the sun would measure 12° for the day. "If the shadow," says Prof. Frost, "shortened six inches as it turned through a right angle (six hours) the observation was made at the pole. On April 21, such a rod would give a shadow nineteen feet eleven inches long." There is no local time and no longitude at the pole. Observations made at a distance from the pole are more difficult, and our adjoining illustration fairly explains the hand sextant that is used. At sea, the horizon is easily fixed upon; on land an artificial horizon made with a dish of mercury or glass answers the same purpose, and the image of the Sun, Moon or Star, is made to reflect from the primary mirror at the apex of the sextant into the glass through which the "horizon" is scanned. The movable arm on the scale of the curving base shows a number of degrees or fractions exactly double the altitude of the Sun, Moon or Star above a horizontal plane, and this altitude may be subtracted from the noon altitude, showing the observer's true position.



THE SEXTANT.

The observer, holding the handle with his right hand and the sliding arm, *E*, with his left, is looking through the telescope, *A*, and through the upper one of the glasses, *B*, at the horizon. Working the sliding arm, *E*, until the mirror at its upper end, *C*, catches the sun, he so manages it that the rays from the mirror pass downward into the glass, *B*; then through the aperture in the lower part of the sliding arm, *E*, he notes the number of degrees of the circle, as marked on the sextant (sixth part of the circle). The number registered is exactly double the altitude of the sun (or other celestial object observed) above a horizontal plane (either the real horizon or a plane made of mercury). He then deduces his position by comparing this number with his noon altitude in the "Nautical Almanac."*

Who was Arago?

Arago, who died in 1853, after an eventful life, is celebrated for the advancement which science received at his hands through his measurements of the Earth and the Planets, his

*"The American Ephemeris and Nautical Almanac" is a book that has been published annually by Act of Congress since the year 1855. It consists of two parts—the first arranged especially for the use of navigators; the second for astronomers. The first part contains tables naming the positions in the heavens for given dates of the Moon, Venus, the standard Stars, etc., so that knowing so much, together with his other observations, the navigator or traveler by land may learn at what point of the terrestrial sphere he may be.

investigations into the nature of light, and his discovery of the generation of electricity in the spinning of the Earth. The history of Arago is a most interesting and romantic recital. The exploits of his early life, growing out of his attempts to measure the circle described by the Earth's surface on a line from north to south, would fill a volume by themselves.

When did Leverrier die?

Leverrier died in 1876. The Astronomical discovery which has made him famous, has been talked about in the paragraph concerning the Planet Neptune.

Fig. 174. ORION.

Who was Rosse?

In April, 1842, the Earl of Rosse, an Englishman, erected at Parsonstown, not far from Dublin in Ireland, the largest telescope known up to that date. This instrument cost one hundred and fifty thousand dollars. The metal reflector, or mirror, in this telescope, weighed three tons, and was annealed (gradually heated and cooled) sixteen weeks in order to prevent the least cracking or warping of the great mass of metal. There is no rainbow wanted in a great telescope, and yet "all the trouble in the world" has to be lavished on the instrument to avoid that appearance, and this mirror or reflector is one of the principal devices to that end. With the twelve-ton telescope thus constructed, the mist in the Milky way, the double Stars, the surface of the Moon, and the Nebulæ were gazed upon with new emotions, and the limitless character of the Universe impressed upon the beholder. Lord Rosse died in 1867. Telescopes were later made by Alvan Clark, of Boston, and by German and French opticians, much larger in magnifying power than that of Lord Rosse. An invention by Newton which made the use of silvered glass possible in place of the enormous mass of metal previously required for a reflector, led to the practicable enlargement of the telescope. There is little doubt that men will, one of these days, bring the Moon within a few miles of the Earth, and settle all questions as to its utter desolation and sepulchral absence of life.

Who was Proctor?

Perhaps the best known Astronomer in our times was Richard A. Proctor, of England. His thorough learning in Astronomy and its attendant studies was conceded, and his efforts to get the sublime phenomena of the science in full view of the people met with success. In 1873 and 1874, he lectured in the principal cities of America, presenting magic lantern pictures of the heavenly bodies as seen in the largest telescopes at the most favorable times, and reducing the troublesome operation of getting "a good look" at Jupiter, Mars, the Moon, the Sun's spots, and, above all, the Nebulæ, to a luxury. Mr. Proctor's efforts in mapping the Stars stamped him as an indefatigable

worker for the real advancement of human inquiry He had taken his residence in America, at St. Joseph, Mo., when he suddenly died, and was mourned as the one man who had done most to educate the people in Astronomy. He wrote the great article on Astronomy in the ninth edition of the Encyclopedia Britannica, He died of yellow fever while in New York, September, 12, 1888, All his books are interesting to the general reader.

Where are the leading Observatories?

Millions upon millions of dollars have been expended upon the science of Astronomy, and its present demands upon the productive capacity of the people are extraordinary. Observatories have been erected in all parts of the world, fully equipped with the appliances necessary. Probably the most celebrated structure of this kind is at Greenwich, near London, under the supervision of Mr. Airy, the Astronomer Royal of England, a man of great attainments and ripe with many years of experience. Six observers and six computers assist him in his eminent labors. Mr. Adams, the co-discoverer of Neptune, was stationed at the Cambridge Observatory, in England. There are great observatories at Oxford, England and Edinburg, Scotland. On the Cape of Good Hope is one of the first-class observatories of the world. Another is situated at Madras, in India. In France, learned Astronomers nightly labor in the observatories of Paris, Marseilles, Nismes and Toulouse; in Germany, at Berlin, Gottingen, Dantzic, Konigsberg and Bonn; in Russia, at Pulkowa and Dorpat; in Italy, at Florence, Naples and Milan; in Austria, at Pola, and in the United States, at Washington (where the Moon of Mars was discovered), at Ann Arbor (where Professor Watson, an Astronomer of world wide fame, now of Madison, Wis., found so many Asteroids, and did the heaviest labors undertaken in America, outside of Washington), at Cambridge, Mass, and at all the principal colleges in the country. Leland Stanford, one of the men who made a vast fortune out of the Pacific Roads, lost an only son, and endowed a University in California with more money than had ever before been given away. The Lick Telescope is a part of this gift.

Charles T. Yerkes gave a great Telescope to the Chicago University, and the empty tube with its mountings, was one of the great sights at the World's Fair of 1893. The vast instrument stood in the Street of Nations in the Manufactures Building. The observatory for the Yerkes Telescope is at Lake Geneva, Wisconsin, and the ground was donated by John Johnston, Jr. Chicago possessed a large telescope for many years, and with this, Professor Burnham carried on studies of double stars that have made him famous throughout Europe.

What is the most salient aspect of modern Astronomy?

Spectroscopy. The application of Kirchhoff's theory of light-waves to the study of the Universe; the measurement of light-waves; the record of star-spectra by photography—the camera being attached to the spectroscope,* and both to the telescope.

What else does the Spectroscope do?

It assures us that the tail of the comet is not illusory, but made of matter. It sorts out the gaseous nebulæ and determines what star clusters are not nebulæ. It reports as authoritatively upon the Becquerel rays, and upon the auroral lights, as upon the most weighty of metals. It detects motion when no sense of man nor any other instrument would be of use. Again, on the other hand, it capriciously acquaints man with the inadequacy of all his theories—even as to the Spectroscope itself, for Matter changes its spectrum with its electric environment, and offers more perplexing problems with each epoch of thought. Perhaps Dr. Roentgen turned the world of theory over Nov. 8, 1895, when he first saw the effects of the rays. The march into confusion has been rapid since then. But of all human instruments, the Spectroscope is the most noble. The German, Kayser, has undertaken a five-volume work on Spectroscopy. Scheiner's large book has been translated by Frost.

How accurate have Spectroscopes become?

Frauenhofer named the black lines that crossed the Sun's spectrum with the alphabet from A to I. The D line (in the yellow) made by burning sodium, appears as a single line in

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*See the Spectroscope, p. 213, and Photography, p. 319.

small instruments, and so appeared to Frauenhofer. But in finer instruments it is double. A variation in the modern scale to the extent of one two-hundredths of the space between this double line can be registered. It is by the shifting of lines sidewise that bodies are known to be approaching or receding. One star may also be known to come between us and another star—as at the star Algol every two days and twenty hours. The coronal or equatorial streamers of the Sun are known to revolve with the Sun.

What is the chief use of the Spectroscope?

In the fires of the outer universe Matter is so distended and separated into elementary parts that the minute divisions of the modern Spectroscope uncover many secrets man could never have learned in an earthly laboratory. To imagine the heat of the Sun one must know that Iron is both a radiance and a vapor at the Sun, and that the vapor is comparatively so cool (although it is hot enough to be a gas) that it hinders the rays of still hotter Iron that shine beneath it. The impulse given to Chemistry by the celestial discovery of Helium, Coronium, Aurorium, Nebulum, Actinium, etc., has aided in the present almost metaphysical research into the constitution or even the birth of Matter, and both Astronomy and Chemistry have set aside vast areas of knowledge to the exclusive uses of Spectroscopy.

What does the Spectroscope say of the Stars?

It tells us they are Suns, like our Sun, and in varying stages of combustion. It even classifies them, and tells us what class of star our own Sun belongs to. Father Secchi and Vogel were the pioneers in this classification. Huggins, Draper and Pickering have been the foremost photographers of star-spectra. Scheiner has set up practically seven classes, but all students agree on at least three "types" of stars, namely: Type I—Like Sirius, Vega (all the white and blue stars); new suns, white-hot suns, burning up all vapors, or nearly all; spectrum vivid at the violet end; fine cross-lines if any, for there are not enough vapors or clouds to absorb and stop the light of the continuous spectrum or "rainbow". Type II—Like our Sun, Pollux, Capella, Arc-

turus; yellow stars; suns with masses of vapor about them; the violet end much less vivid than type I; the black cross-lines sharp and prominent; that is, the fire is past its acme of heat and splendor. Type III—Like Antares, Aldebaran; red stars; suns about which the vapors have accumulated and cooled to such a degree that the metals form chemical compounds; these compounds make bands and fluted appearances instead of clean-cut lines. Darkness is closing in on these stars. Our Sun will outshine them for ages as Vega will outshine our Sun for ages.

What about the new star in Perseus?

At 20 minutes of 3 A. M. of February 22, 1901, civil time, Dr. Thomas D. Anderson, of Edinburgh, Scotland, in looking at the sky without a telescope, saw a star of the third magnitude in the constellation of Perseus. He supposed it would prove to be a comet. Within twenty-four hours this new (Nova) star increased 10,000 times in brightness, and outshone Capella, the largest star in the region. Algol (the "devil-star" of the ancients) was also a neighbor. In America there were fleecy clouds in the sky, and the wonderful spectacle—the largest new star since the one in the time of Tycho Brahe—was seen by only a few people. It was too far distant to measure, and threw out nebulous rings to inconceivable distances. It rapidly decreased in size and was of the twelfth magnitude within a year. The spectroscope classified it as a planetary nebula. It was a previously cool world on fire, and the conflagration may have happened ages ago, and surely did happen centuries ago. It sent nebulous matter into space that is possibly approaching the solar system. It is thus that comets may form and fly.

What do you mean by saying civil time?

Astronomers use a peculiar clock and keep a peculiar reckoning. When Nova Persei was found, it was Feb. 21, 14 hours, 40 minutes, sidereal time, and Feb. 21 of sidereal or star time did not close until noon of Feb. 22, of solar or civil time. Astronomers have agreed that when (approximately) the last or eastern side of the Great Square of Pegasus, goes past the zenith of Greenwich, say, every day, it shall be 0 hours, 0 min-

utes, 0 seconds, and the sidereal clock counts 24 hours, losing four minutes of solar time each day. Three great theoretical celestial lines, one from the pole, another outside the equator, and another in the Zodiac, all come to a point called (formally) "the first point in Aries." When this point "culminates" it crosses the zenith, and all stars are reckoned as having so many hours, minutes and seconds to the right of this point, or right ascension. The distance outward from the pole star toward the south pole stars, is reckoned in degrees. As astronomy is overhead, all maps are wrong-end-to, and also nearly all astronomical photographs are wrong-side-up. This "first point in Aries" means nothing visible. It is like the Easter full moon of the church. It is an astronomical myth. If you look out a little south and east of Algenib (in Pegasus) in the summer time, into the constellation Piscis, where there are three little fourth magnitude stars, you will be near the present junction of all three of the assumed lines that cut the heavens and are used by astronomers. This is called "the first point in Aries," although Aries has not been there for ages.

Describe Pegasus.

Four second magnitude stars, set wide apart, form the Great Square. From the northeastern corner a line of Andromeda-stars forms the neck of a horse, such as the ancients would draw; at the other corner is a little tail-star. This conspicuous Square is passing over head all through the latter half of the year. From the pole-star outward, on the western side of the Square, first to come up, are Scheat and Markab; on the eastern side, last to come up, are Alpheratz and Algenib. If you wish to strike near the line of 0 hours, 0 minutes, 0 seconds, of right ascension, go upward from Algenib, to Alpheratz, to Caph, which will be the eastern big star in the W of Cassiopeia, and onward to the North Star—Caph is half way from Alpheratz to the pole. This line is very near to the "equinoctial colure"—Caph and Alpheratz are particularly close. From this equinoctial colure all other stars to the east, all round, are mapped as having 1, 2, 10, 20, 23 hours of right ascension, as the case may be.

Is there another horse in the sky?

Yes. Saggitarius, down at the summer-end of the Milky Way, forms a still better horse. The scene from Saggitarius upward to the Swan on the western plains and in Asia on summer nights, has never yet been worded.

Tell me of the nebula of Andromeda.

Half-way between the Great Square of Pegasus and the W of Cassiopeia is a world-system in process of formation, according to the hypothesis of La Place. It is a whorl of gaseous matter, well lit up with a central nucleus that every little while looks like a star to some great astronomer. Sept. 20, 1898, Seraphimoff, of Pulkowa, announced that at last the sun of Andromeda's nebula was shining. Merlin, at Volo, Greece, telegraphed that the star had come. Rayet, at Lyons, France verified Seraphimoff. But Barnard, at Williams Bay, Wis., put the 40-inch Yerkes telescope on the nucleus, and it was still the gaseous dull body it has appeared to be for centuries. There seems little doubt that our solar system once appeared in the heavens a disk of gaseous matter, whorling as the nebula of Andromeda probably whirls. The nebula is photographed regularly and is, so to speak, never out of the sight of man. As in the case of Mars, there is a hint of auto-hypnotism in the eyes of the astronomers.

Do the ancient names cling to the stars?

In many cases, yes. In Arided, the tail-star of the Swan, it is possible to trace the Arabic Ad-dadjadja, the Hen. In Algenib, Arabic Al-djanb, the Side. Alpheratz is Al-faras, the Horse, thus betraying the ancient constellary name of what we now call both Andromeda and Pegasus, for, as we have said, these constellations make a great horse in the sky. Markab is Arabic for "nag." Aldebaran, in Taurus, is from Al-dabar, the Follower, because Aldebaran follows the Pleiades. The sense of "following" is correct, because our point of view is from a ball, and the stars seem to go *around* it, actually following in each other's paths. The Arabs called Orion, Al-djebbar, the Giant. Thus the first star in Orion, Betelguese, is probably

Beth-el-djebbar, the House of the Giant. Vega was called the Eagle-that-falls; Altair, out further toward the Zodiac, was the Eagle-that-flies. This seems to hint at a superior brightness in Altair (Arabic, *Attair*), which that star now by no means possesses, although it is a marvelously brilliant star for its apparent size. Possibly the stars have changed ranks during the ages. The Pleiades must have been brighter. Space will not permit us to pursue this pleasing excursion into philology.

What of the North Star?

At a conference of astronomers at Williams Bay, Wis., in September, 1899, Campbell announced that he had spectroscopically resolved the North Star into a revolving system of at least three bodies. Two of these bodies revolve about each other in about four days. These two revolve about an invisible body in a cycle of years as yet undetermined. Hartmann, by study and photographs, has corroborated Campbell's views.

What did Bessel, of Konigsberg, do?

This wonderful man gave us our first idea of the distance of a star measured in yardsticks as long as from the center of the Sun to the centre of our Earth. He chose a small star, which proved to be double, numbered 61 in the constellation of the Swan. It had the greatest proper motion of any star he knew, so he judged that it ought to be nearest to the Earth. By means of observing two neighboring stars with reference to 61 Cygni he was able to detect the apparent ellipse that the Earth's orbit made the star seem to perform. Let us suppose the star to be directly over the earth. The ellipse which one of the bodies makes in a year is as one of our old copper cents to a point three miles above it. The star is 400,000 yardsticks away, and the yardstick is itself 93,000,000 miles long. In light speed 61 Cygni is six years away; the sun is about 8 minutes away. (See p. 488.)

What is the Saros?

An astronomical cycle, probably first named by the Chaldeans, and applied to eclipses of the Sun at a period at least 700 years

before Christ. In 1900 this Saros was computed to be 6585.32116 days. In these 6585. . . days the centres of the Sun and Moon return nearly to the same relative positions, and the same series of eclipses begins again. Thus, if the Earth did not turn on its pole, there would be an eclipse nearly in the same longitudinal region again at the end of the cycle. But the one-third of a day enables the Earth to turn 120 degrees, which throws the next eclipse that much further west. In about 54 years the eclipse of any cycle returns to about the same longitude, but 600 miles north or south.

Is there a solar cycle, too?

Yes. It is about 1,150 years long. Solar eclipse cycles are about 30 years apart, some working north on the Earth, others south. Let us stand on the north pole; there we behold the smallest and briefest possible partial eclipse, the Moon barely grazing the edge of the Sun. A solar cycle is thus begun. At every return of the Saros, this partial eclipse will move southward, its magnitude increasing for 200 years. It next becomes annular or ringlike, first at the north pole, because the Moon's shadow is touching the Earth. This shadow will increase to totality and decrease for 750 years, during which time it has again traveled the Earth downward to the south pole. Then 200 more years are covered by the outgoing partial stage. There have been about sixty-four returns of any particular eclipse—that is, as regards the Sun and Moon themselves, and their centres in line with some part of the Earth. While one solar series is going south, another solar series may be going north. The chain which reckons the total eclipses of 1904, 1922, is going south. The chain of 1919, 1937, 1955, is going northward. Another chain counts the years 1842, 1860, 1878, 1896. 1914, 1932, etc.

How long do total eclipses last?

From 11 seconds on Sept. 29, 1894, to 6 minutes 46 seconds August 18, 1868, as recorded in recent years. An eclipse could conceivably last the smallest instant of time, or for 8 minutes The eclipse of each Saros is of about the same length.

Is the Moon's place in the skies computed accurately for any moment?

No. The Lunar Theory, probably the most complex and painstaking mathematical work of the human intellect, is still compelled to deal with motions that can be computed only in their cycles. At the eclipse of 1900 in the Southern States the Nautical Almanac foretold a totality nearly four seconds longer than the heavens produced.

What has Von Oppolzer done?

In 1887 he published a book at Vienna, "Canon der Finsternisse" (List of Eclipses), giving approximate calculations for the visibility of 8,000 solar eclipses from B. C. 1208 to A. D. 2162, with 160 charts showing the tracks of the principal events.

What American is celebrated for his work on the lunar tables?

Professor Newcomb. But these great mathematicians are harvesters and inheritors of ages of knowledge. Lagrange, Hansen and Bessel will be forever famous for the union of genius and industry that they evinced.

What in part has resulted from this fine figuring?

Variations of latitude have been discovered at certain observatories, and a polar motion within a space less than 60 feet, with a cycle of 427 days, has been mapped. The surface of the Earth also acts elastically.

Speak further of the Lunar Theory.

Hansen produced tables in 1857 that, with the corrections of Professor Newcomb, are still in use. The original discrepancies were never more than one or two seconds of arc.

What does "secular acceleration" mean?

The body is observed to go faster, from age to age, and yet to revolve further away. This observation does not accord with the theory of gravitation. In 1865 Delaunay returned to Kant's theory of tidal friction, which had been partly computed in 1853 by Ferrel, and Delaunay made the remarkable suggestion that as the friction of the ocean on the land under the Moon's influ-

ence must retard the Earth's motion around its own pole, to that extent it must set our measure of time wrong, for we have no other way of counting a second or a minute than as a fraction of a day.

What amount of time was here involved?

Counting from age to age, one-tenth of a second in 10,000 years—supposing the earth to be retarded that much—would account for the increased speed of the Moon. Again, unknown planets revolving inside the orbit of Mercury, would clear up the question of both the Moon's and Mercury's perturbations, and the photographic plates of the eclipse of 1900 contained six suspected markings, but all of bodies very small, if planets.

What else is known of the Sun's corona?

In Sumatra, at the eclipse of 1901, a sun-spot surrounded with flowing wells of gas (faculæ, prominences) was on the limb of the Sun at the moment of total eclipse. It was then demonstrated that the coronal streamer above these torches or faculæ was correspondingly long. The spots make coronal outpourings that reach far past the Earth. The magnetic storm that stopped the telegraph all over the earth Oct. 31, 1903, was caused by a new sun-spot, or was co-incident with it. This was the gist of Herschel's theory, but he could not prove it.

What are Shadow-bands?

In the eclipse of 1870 they were sketched on an Italian house. They covered the entire side of the house in oblique thick, wavy lines of light about a foot apart. They probably attend all total and annular eclipses, especially as totality approaches. They are as yet a puzzle.

The Advance of Science

May I hope to keep in touch with Advancing Science?

Certainly. There is no limit set upon what we may learn. The grandest star in the Universe is but a thing, in itself by no means so complex as a human being. However, before entering on the following chapter, it would be highly profitable to read the chapters on Chemistry, Photography, Spectroscopy, the X Rays, the final portions of Astronomy, and particularly the matter printed in fine type at pages 222, etc. In this way, the operations of Frauenhofer, Lenard, Hittorff, Geissler, Crookes, Langley, Lockyer, Roentgen, J. J. Thomson, Curie and other wonderful men, in unveiling the secrets of light, of rays, and of emanations may be intelligently followed.

Is the old Theory of Matter changing?

It is evolving. It is growing more complex, but is practically still founded on grounds held by the ancients.

Can I be aided by the Newspaper Press?

Yes. Study the scientific or physical chapters of this book, and become acquainted with the theories there advanced and the results attained through those theories. Then, in the newspaper, if a scientist mentioned in this book is himself the signed author of the article, you will find that you understand him, and you of course can believe him. If, on the other hand, a reporter has interviewed the scientist, or a correspondent announces some new attainment of science, or what he may think is a new attainment, you will be qualified to form an intelligent opinion of the value of the news. The modern press is to

be criticised for compelling its writers to make what it calls a "story" out of almost every fact that is treated of; yet it is idle to reject all of its information as useless. The world heard of the X Rays, and of Radium, very usefully through the newspapers, but as soon as Radium ceased to be a "story," the almost incredible things regarding it, mention of which follows in this chapter, were neglected by the public press in order to make room for the customary divorce scandals and field sports. Yet science cannot fail to occupy more and more space as profitable news.

What is the new Science?

It is the abandonment of the Hydrogen atom as the lightest or smallest Matter in the Universe. A good many years ago Prof. Dolbear agued logically that when man should investigate Matter closely enough, there would remain only Motion in the Ether. The scientists now teach Ether, Energy, Matter, but are inclining to believe that Energy and Matter are interchangeable.

What was the old view of Matter?

That Matter could only be solid, liquid, or gaseous. But after the cathode rays and the X rays were discovered, Sir William Crookes argued that there was a fourth or radiant state of Matter, and this view is now a part of the new knowledge.

What are the known facts in support of a theory that etherealizes Matter?

It is our purpose, now, to deal with a few of those facts briefly, but to distinctly show their logic, which also pertains to all the facts known. Five Elements, it has been learned, give off electrons or corpuscles, without manipulation by the physicist, it being impossible to either retard or accelerate nature's actions. The electrons are a thousand times smaller than the atoms previously regarded as the beginnings of Matter, and are always charged with negative electricity. Probably all other Elements, if excited by heat or electricity, act in a similar way. The cathode rays fly from a flame, a red- or white-hot metal, or from the metal making the negative electrode or pole of a vacuum tube.

Tell me about the Periodic Law.

When the chemists became able to weigh all the Elements that had been isolated, they placed those Elements in the regular order of their increasing weight.

What impressed Newlands?

The eighth Element would exhibit characteristics similar to those of the first, or of the sixteenth, or twenty-fourth. It was exactly as the keys on the piano, where the keys C, D, E, F, G, A and B lead up to C again, which harmonizes with the C left behind. Or, you may sound the musical syllable *do*, and then sound it higher; the higher one will be the eighth piano-key letter away. Here we have the chemical Octaves of Newlands.

What were the triads of Dobreiner?

After the Elements were tabulated according to their advancing weights, Dobreiner found groups of three that would act much alike, such as Calcium, Strontium, Barium; or Chlorine, Bromine, Iodine; or Sulphur, Selenium, Tellurium. He then noted that the atomic weight of the first and last of a triad, if added together and then divided by two, would very nearly equal the atomic weight of the middle Element in the triad; for instance, Sulphur 32.1; Tellurium 127.5; mean, 79.8; atomic weight of Selenium, the middle Element in this triad, 79.2. Thus the chemists became aware of some sort of relationship among the atoms.

Now what did Mendeléeff do?

Mendeléeff (sometimes spelled Mendelejeff) spread Newlands' Octaves of the Elements (by weight) into a table at first seven columns or Elements wide; he would place the eighth Element back at the first column; the Elements in each column reading downward would exhibit characteristics that were similar. But to make this first table work theoretically, he was forced to leave vacant two places in the third column (Group III) and one place in the fourth column (Group IV). In 1871 he became so sure of the correctness of his "Periodic Law" that he theorized three then undiscovered Elements and named them Eka-Boron, Eka-Aluminium, and Eka-Silicon.

Table of the Periodic Law. (Mendeléef, 1904.)

Series	Zero Group	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
0	*x*								
1	*y*	Hydrogen H=1·008							
2	Helium He=4·0	Lithium Li=7·03	Beryllium Be=9·1	Boron B=11·0	Carbon C=12·0	Nitrogen N=14·04	Oxygen O=16·00	Fluorine F=19·0	
3	Neon Ne=19·9	Sodium Na=23·05	Magnesium Mg=24·1	Aluminum Al=27·0	Silicon Si=28·4	Phosphorus P=31·0	Sulphur S=32·06	Chlorine Cl=35·45	
4	Argon Ar=38	Potassium K=39·1	Calcium Ca=40·1	Scandium Sc=44·1	Titanium Ti=48·1	Vanadium V=51·4	Chromium Cr=52·1	Manganese Ma=55·0	Iron Fe=55·9 Cobalt Co=59 Nickel Ni=59 (Cu)
5		Copper Cu=63·6	Zinc Zn=65·4	Gallium Ga=70·0	Germanium Ge=72·3	Arsenic As=75·0	Selenium Se=79	Bromine Br=79·95	
6	Krypton Kr=81·8	Rubidium Rb=85·4	Strontium Sr=87·6	Yttrium Y=89·0	Zirconium Zr=90·6	Niobium Nb=94·0	Molybdenum Mo=96·0	—	Ruthenium Ru=101·7 Rhodium Rh=103·0 Palladium Pd=106·5 (Ag)
7		Silver Ag=107·9	Cadmium Cd=112·4	Indium In=114·0	Tin Sn=119·0	Antimony Sb=120·0	Tellurium Te=127	Iodine I=127	
8	Xenon Xe=128	Cæsium Cs=132·9	Barium Ba=137·4	Lanthanum La=139	Cerium Ce=140	—	—		— — — (—)
9		—	—		—	—	—	—	
10	—	—	—	Ytterbium Yb=173	—	Tantalum Ta=183	Tungsten W=184	—	Osmium Os=191 Iridium Ir=193 Platinum Pt=194·9 (Au)
11		Gold Au=197·2	Mercury Hg=200·0	Thallium Tl=204·1	Lead Pb=206·9	Bismuth Bi=208	—	—	
12	—	—	Radium Rd=224	—	Thorium Th=232	—	Uranium U=239		

What does Eka mean?

It is a Greek prefix meaning about the same as the Latin *ex*—out of, from within, etc. Afterward Ramsey called his Eka-Radium, Ex-Radio. So now the chemists went on the hunt for, say, Eka-Boron, and Wilson, the Scandinavian, found Scandium. Mendeléeff had predicted an atomic weight of 44, (the exact weight of Scandium) an Oxide composed of Eka-Boron 2 atoms and Oxygen 3 atoms, and the oxide of Scandium showed the formula Sc_2O_3; and Mendeléef had foretold three other chemical characteristics that this like-Boron Element, Scandium, was proved to possess. Then followed the discovery in France of Gallium (Eka-Aluminium) and in Germany of Germanium (Eka-Silicon), which met the five different tests of Mendeléeff's prophecy, and the Periodic Law was accepted as something that human reason could not overthrow. Mendeléeff has said that he little imagined he would live to see the discovery of the three needed Elements.

Has there been a change in the computation of the weight of Oxygen?

Yes. The Chemistry of Liebig was computed on the theory that one Oxygen atom weighed 15.96 Hydrogen atoms (Hydrogen being the real measure). The latest apparatus and instruments seem to reduce this weight to 15.879. But by placing Oxygen at an even 16, and Hydrogen (the prime number) at 1.008 instead of 1, the atomic weight of about thirty Elements will come out with even numbers of Hydrogen atoms, thus greatly economizing the mathematician's time and minimizing error. So Mendeléeff has adopted this system, (and it is now called International), whereby 16 Oxygen equals 1 Hydrogen.

What next happened to Mendeléeff's table?

He was compelled to make an eighth group of outside triads that did not fit in the big table (and he never had counted Hydrogen anyway).

Then what happened when The New Science came?

As Prof. Dewar lowered and lowered his temperatures to nearly 260 degrees Fahrenheit below zero, Element after El-

ement was frozen out of the air and out of Hydrogen. These their discoverers named or recognized as Helium, Neon, Argon, Krypton, Xenon. But not one of these Elements would combine in any chemical way with any other Element known. So Mendeléeff placed them, as you see, in a Zero Group ahead of Group I, leaving them to resemble themselves, and hinting that other equally repellant gases would some day fit in at series 5, 7, 9, etc. This philosophical feat of Mendeléeff established the Periodic Law, for now the chemist might know a great deal about an Element upon learning its atomic weight. But still the Hydrogen atom, as the lightest or smallest matter in the Universe, did not account for the recurring likenesses of the Elements.

Now may we begin with the "Rays"?

Yes—we have shown how the arc-light got inside the bulb (p. 95), and how electric machines were made to intensify their discharges. For fifty years the peculiarities of "fox-fire" (*faux-feu*) and fluorescence puzzled all the investigators. When the cathode rays in the tubes were studied by Geissler, Hertz, Hittorff, Lenard, Stokes, and others, Niewenglowski took Calcium Sulphide (the basis of luminous paint) exposed it to sunlight, and then by its means secured a photograph in a dark room and through a thin sheet of aluminium. Twenty-three hours were required; these Niewenglowski rays were light-rays, and could be reflected and refracted, like sunlight. In fact, they were caused by stored sunlight.

Let us return within the Tube, and to the Negative Pole.

You are to clearly understand that the high current of electricity enters at the positive end of the tube, goes across and leaves at the cathode, and yet there is projected from the cathode pole, back into the positive end, a wonderful stream of radiance. As stated at page 223, Prof. J. J. Thomson and others (Hertz particularly) set out, with the most delicate electroscopes, gold-leaf apparatuses, and the various magnets, to weigh, measure, deflect, and otherwise study this negative radiance. This radiance was found to be emitted in straight lines, to

push against matter, to travel with a velocity as high as 90,000 miles a second, to cast a shadow if dense metal were interposed, to heat to almost any degree if converged on an object, and finally to be composed of electrons or corpuscles one thousand times smaller than anything that flowed from the positive pole. Thus at last man thought he had discovered a real material difference between the two electricities.

What did Lenard do?

He made a tube with aluminium instead of glass at the positive end. The electrons went through this tube and once outside the tube were called Lenard rays. They were still the same electrons. By their means it was learned that Matter does not absorb sunlight and electrons in the same way—whatever electrons were, they were not what we call light.

Was it at this stage that Dr. Roentgen discovered X rays?

Yes, except that Dr. Rœntgen at this time supposed the radiance (electrons) was light—that is, waves of ether instead of a bombardment of matter. Dr. Rœntgen determined that X rays were different from cathode rays (electrons).

What were S rays?

M. Sagnac found that be could deflect some of the X rays, and change their nature. He named them S rays. When the X rays strike a surface that they will not penetrate, they "splash" instead of rebounding, as light does, at the angle of incidence. Goldstein found that X rays changed their characteristics by passing through perforated plates of metal—hence Goldstein rays. At about this stage Prince Krapotkine opined that all matter would be found to possess radio-active qualities.

Was more learned about the Cathode rays?

Yes. They beat on the glass of the vacuum tube, and the glass sent forth X rays. The cathode rays (electrons) differed from light in this astonishing regard: light may refuse to freely enter either heavy or light bodies; thus cork or iron may "keep out light". But bodies of matter absorb electrons according to the density of those bodies. The heavier the body, the more electrons will penetrate it.

What did Becquerel do?

When he learned that Niewenglowski had obtained metal-penetrating rays from Calcium Sulphide outside of a vacuum tube, without high currents, or any currents of electricity, he placed a piece of the Element Uranium on a photographic plate covered with black paper and put it in a dark room. Rays from the Uranium went through a copper cross and the cross was dimly photographed. The Uranium would do this permanently, while the Calcium Sulphide must be charged with sunlight. Pure Uranium was most powerful as a ray-emitter, but any Uranium compound would emit the Becquerel rays.

What did Becquerel conclude?

He felt that if the cathode pole in the vacuum tube under high excitement gave off rays, and if Elements outside the tube without apparent excitation gave off rays, then Matter possessed a property, Radio-Activity, in accordance with Krapotkine's guess, and he so named that property. This is the same idea as Sir William Crookes' theory that all Matter may appear to be solid, liquid, gaseous, or radiant, according to its temperature.

Was it here that M. and Madame Curie took hold?

Yes. With the aid of Debierne, these celebrated physicists argued that, as Uranium comes from an ore called pitchblende, and as they could sometimes obtain chunks of pitchblende more ray-emitting than was pure Uranium itself, there might be undiscovered Elements in pitchblende. The result was the discovery of Radium, Polonium, and Actinium. Radium compounds (the Bromide, the Chloride, etc.) have been obtained that are 100,000 times more powerful than pure Uranium. The wonderful properties of Radium are sketched at page 223. The world was even more astonished by the Curie discovery than by Rœntgen's, and we may say that the new philosophy of Matter and the break-down of the atom was now fairly begun. It was theorized that pure Radium would be 1,300,000 times as powerful as pure Uranium. You may now turn to Mendeléeff's table to find Radium's Group (or column of Elements that resemble Radium), and, of all these, Barium is chief, and is with the greatest dif-

ficulty dissociated from Radium in the final refinements. Notice in Mendeléeff's Group II, that man had long used several of these Elements as paints and preservatives. Radium gave a distinct and many-lined spectrum in whatever compound it was presented to the spectroscope. It is an Element, as much as Gold is.

Must we now return to the Vacuum Tube?

Yes, because we had debated only the cathode or negative pole. As the electricity passes across, visible only as it carries particles of matter with it, J. J. Thomson now finds that only particles will come away that conform to the theorized size of the Hydrogen atom. These are 1,000 times larger than the electrons, and whereas the electrons are always negative, the "ions" coming from the positive pole are always positive. They do not travel so fast as the electrons. They carry about the same electrical charge as a Hydrogen atom (theorized). They are deflected but little, and only by powerful magnets.

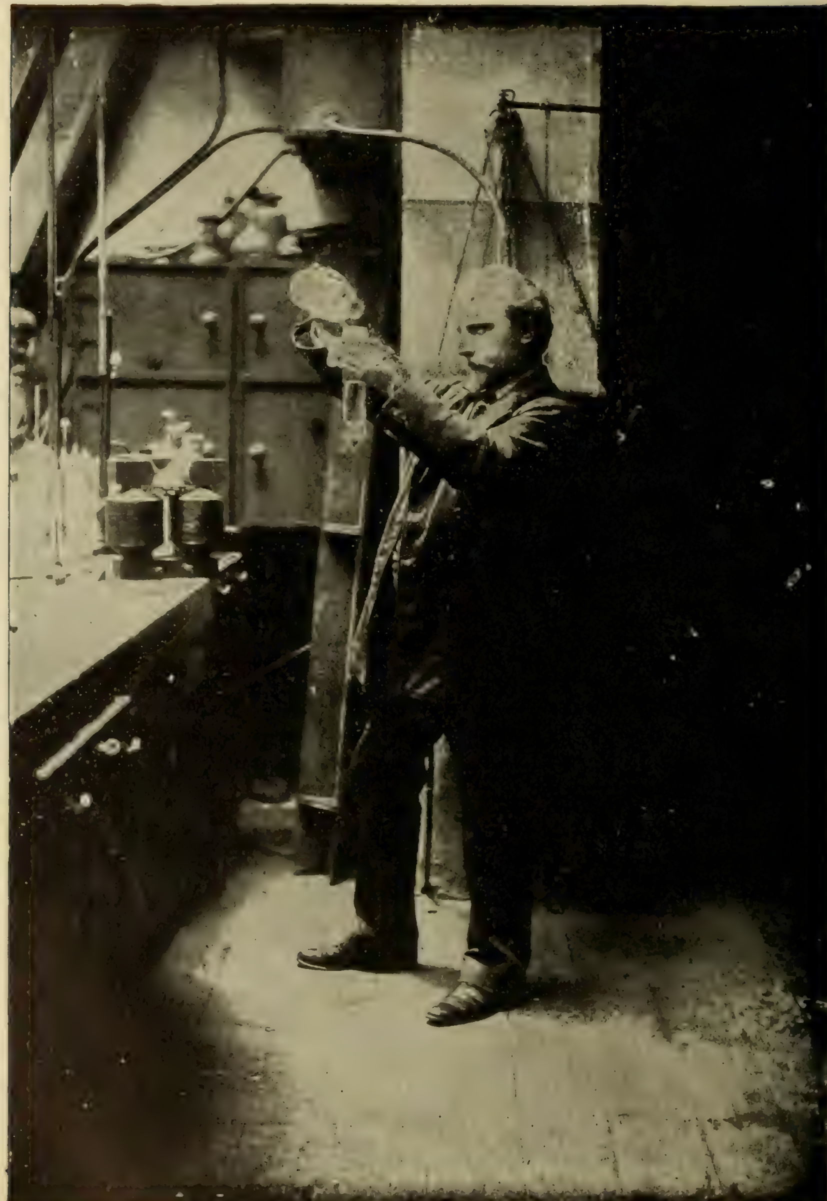
What next?

Man now had three kinds of things in or coming from the tube—ions, electrons, and X rays. We will now call them Alpha, Beta, and Gamma rays—(A, B, G, the first three letters of the Greek *Alphabet*),—for no sooner were the three different things studied closely by the light of Radium, than Alpha, Beta and Gamma rays were detected coming from glowing metals, gas-flame, candle-flame, Radium, sunlight, etc. So the Crookes tube and the Ruhmkorff coil were only the means of admitting man into a new domain of knowledge. Radium takes "X ray pictures;" there is no ascertained difference. Radium phosphorizes matter, just as sunlight phosphorized Niewenglowski's Calcium Sulphide. A tube of Radium Chloride was photographed in the daylight. It was then put in a dark room, phosphorized itself, made itself visible, gave light for the photograph and photographed itself. All electrons phosphorize bodies and electrons are the Beta rays.

Describe Radium as far as we have proceeded.

It throws off rays, and the Beta rays are visible under Crooke's

M. CURIE EXPLAINING THE WONDERS OF RADIUM AT THE SORBONNE. PARIS



LIQUID AIR. PROF. DEWAR IN HIS LABORATORY.

spintheroscope (page 223). They are negative, swift, and small, —in a word, they are electrons. Radium throws off Alpha rays that are like ions—positive, slower, and weak in action. It throws off Gamma rays, said to be absolutely undeviable, and these rays are supposed to be the agents in taking the Radium "X ray pictures." The most notable thing for the student here is that the Beta rays of Radium seem to be of the same nature as electrons coming from the cathode of the Crookes tube. In an electroscope, where two gold-leaves are spread apart by a charge of electricity, the leaves come together at once upon the approach of a tube of Radium compounds. The Beta rays flying from the tube have reached the field of the electroscope. The Gamma rays (supposed) of Radium have been known to go through a foot's thickness of solid Iron.

What is the object of so much of this talk about different rays?

To give you a firm grasp of the new theories—the break-down of the atom into electrons, and the logical conclusion that if an electron were at rest, it would cease to be anything we could call Matter. Dolbear guessed as much a good many years ago. All mental and other healers noted something of the same denial of Matter ages ago.

Go on then with Radium.

Radium was soon discovered to have a power of "laying on of hands." It could make a temporary or false Radium out of any Matter, living or "brute" (page 224). Prof. Curie became so highly charged with Radium that for days he would discharge electroscopes and phosphorize other bodies. He gave off Alpha, Beta and Gamma rays. Zinc, exposed to Radium, became four times as radio-active as Uranium. This led to Rutherford's discovery.

What are Emanations?

It was nearly certain that the three kinds of rays went cut in straight lines from Radium. But Rutherford ran a tube around to a flask in which was a gelatinous white precipitate of Sulphide of Zinc. When a stop-cock was opened, something that was not the rays passed into the Zinc and made it shine in the dark.

Rutherford has named this "something" the Radium Emanation. It is a powerful agent, and if it be a gas, it must belong to the Zero or totally inert group in Mendeléeff's table. Radium Emanation may be frozen out of the air like Krypton, etc., at 150 degrees below Centigrade zero. The Radium Emanation has only been investigated by means of the electroscope, which is thought to be a million times more sensitive than the diffracting spectroscope. The Radium Emanation emits only Alpha rays (ions), and leaves the original Radium temporarily weaker by about 25 per cent of its strength. As the Radium regains its lost strength, the Emanation ceases to be radio-active, and this process man cannot as yet accelerate or retard. Until the Radium regains its original powers, it will not emit Beta or Gamma rays.

What is Radium Emanation X?

Upon subjecting surrounding matter to the Alpha rays (the only known emission) of Radium Emanation, these objects become temporarily more potent than the temporarily de-emanated Radium, and when the Radium Emanation X, or second Emanation, is gathered (which it may be) it emits Alpha, Beta and Gamma rays. Here we are face to face with the logic that Alpha rays are chemical atoms, and that they break down into, or create, Beta corpuscles and Gamma rays. As we have said, as Radium Emanation loses its powers, Radium regains all its strange qualities. No instrument or action of man in releasing natural forces interferes in the slightest way.

When did the transmutation of the Elements first seem achieved?

In 1903 Ramsey and Soddy were endeavoring to obtain a fixed spectrum for Radium Emanation. Gradually the well-known spectrum of Helium made its appearance—the same lines Lockyer had long ago discovered on the sun (hence Helium). Thus, when the ions of Radium Emanation break down, one of the things they do is to regather into the atoms of Helium.

Now what about Radium as a whole?

It has overthrown what we took to be natural laws. It has

transmuted Matter. It is the parent of eight or nine forms of Matter, thus—Radium, de-emanated Radium, Alpha, Beta, Gamma rays, Radium Emanation, and its inert product; from Radium Emanation, Helium, Radium Emanation X and its inert product—truly a most wonderful thing to have one single element to do to Avogadro's hypothesis. And Radium is, as it were, only the bell-wether of the Elements. We already have Uranium, Thorium, Polonium, and Actinium, and the high valency of Sulphur (page 239-262) must hint at radio-active discoveries in other parts of Mendeléeff's Group VI.

Does Radium emit heat?

Yes. In March, 1903, Curie and Laborde demonstrated that a quantity of Radium-compound emitted enough heat to maintain a temperature in the Radium-compound 2.7 degrees Fahrenheit above its surroundings. The heat was believed to be the result of the bombardment of Alpha particles coming back to the Radium whence they had been projected.

Once more, speak of these three Rays.

Probably all matter in high excitement projects them. The negative charge of the little electrons equals the positive charge of the big ion. The Alpha particles do not travel as fast as the Beta particles (electrons). The Beta particles can be deflected by magnets much more easily than the Alpha. Now as to the Gamma rays, they may not be particles of Matter, almost surely are not, but are X rays. When the Radium or any other excited Matter propels its tiny bombs, as seen through the spinthero-scope, there should be a back-thrust against the body of the propelling Radium, and this may cause the peculiar waves in the Ether that Roentgen first discovered. In the vacuum tube the Beta rays seem to generate the X rays at the glass walls of the tube as the Beta rays pass out into the air. It is said that the Gamma rays cannot be deviated by any means whatever. One thing: So far as is known, Thomson's ions and electrons carry Matter, while Becquerel's Gamma rays do not (unless Ether is Matter).

What is Thorium?

It is a gray metallic powder that burns with great brilliancy and becomes the Oxide of Thorium. It was discovered by Berzelius in a Norwegian ore that he named Thorite, after the god Thor, for whom our Thursday is also named. Little could Berzelius have thought to what extraordinary usefulness Thorium would be brought, for after the discovery of Thorium ores in the Carolinas, and particularly in Brazil, Thorium to the extent of 99 per cent was used in nearly all our Welsbach mantles. Berzelius discovered that it was allotropic (p. 241) and we may now reason why. In 1904 Baskerville announced that he had separated Thorium into Elements that he named Berzelium and Carolinium, but it is probable that he was only at the threshhold of the mystery. All Thorium compounds emit Alpha, Beta and Gamma rays.

What is Thorium X?

Rutherford extracted from Thorium a powder one thousand times more radio-active than Thorium itself and named it Thorium X. A month later the Thorium X had become inert and the Thorium had regained its pristine activity, which had been lost during the activity of Thorium X. Meantime, Thorium X had given off Alpha rays and an Emanation, and this Emanation gave off an Emanation X, all in the manner of Radium, and Emanation X emitted Alpha, Beta and Gamma rays. The Emanations of Radium and Thorium have many differences, those of Radium being many thousand times the more lasting, and freezing at a much colder point. In the case of Thorium, as in that of Radium, matter is transmuted by Nature in the presence of the physicist, and he is powerless to prevent or aid the process.

What is Uranium?

It is the Element that opened the way to the mysteries of the cathode rays. In 1789 Klaproth discovered in pitchblende what he took to be an Element, but what was really the first Oxide of that Element. He named it Uranium, after the Greek word for

"celestial," because of the beauty of its colorings. In 1840 Peligot extracted the Oxygen and secured Uranium, a hard but malleable metal the color of iron, tarnishing in air, taking fire very easily and burning with brilliancy to a dark green. For over half a century it has been the Uranium in our porcelain and glassware that gave them their attractive iridescence and opalescence. It was Prof. Stokes (p. 95) who first called the attention of the world to the action of Uranium under light.

How about Uranium evolutions?

Uranium continuously gives off Uranium X, and Uranium X emits only Beta rays or electrons. The Uranium itself emits only Alpha rays. There are no Emanations yet discovered, and neighboring bodies do not become radio-active. As in Radium and Thorium, the balance of decay and revival between Uranium and Uranium X is perfect. A test of five years with examination every 48 hours has shown a radiation by Uranium where a variation in intensity of one one-hundred-thousandth could have been measured.

What is Polonium?

The Curies obtained it in minute quantities from pitchblende. It has not been entirely separated from Bismuth. It gives off only Alpha rays. It rings an electric bell on coming near, and lights up real diamonds. It seems more active than Radium. Its activity seems to decrease with time, which is disappointing to the new theories.

What is Actinium?

It was discovered by Prof. Crookes in October, 1899. It is much more radio-active than Thorium. There is an Actinium Emanation, but it is active for only a few seconds. Actinium makes surrounding objects radio-active. Like Polonium, but little Actinium has been secured.

Of Radio-Activity again, as a whole.

Actual successful experiments and demonstrations have been made on Radium, Thorium, Uranium, Polonium and Actinium. Beginning at the cathode of the Crookes tube, man is now able

to trace Radio-activity to the air of cellars, to mineral springs, to fresh earth—in fact almost everywhere. It is a property of Matter.

What is Asterium?

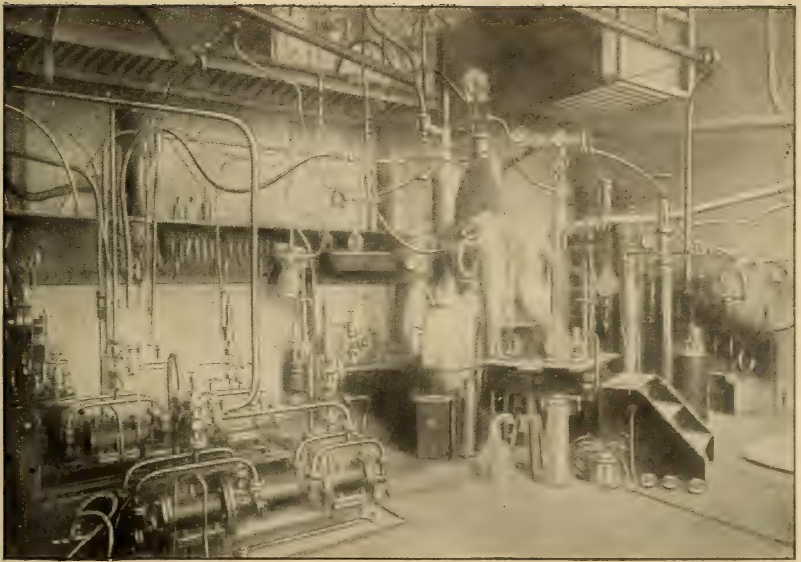
It is shown in a spectrum evolved from only the hottest or blue stars (p. 536). Under the New Theory the star has as yet no corpuscle large enough or powerful enough to form into the atom of any known Element other than this Asterium.

Finally, what is the Ether, under the New Theories?

Mendeléeff guesses that the Ether is the lightest and simplest of the Elements. He would place it where x is in his Zero Group, and ally it with the Argon-Krypton family of Elements that will not combine with any Element whatever. He guesses that the atomic weight of Ether would be about one-millionth that of Hydrogen and its velocity literally immense, hence its power to permeate everywhere.

Am I now any nearer the Truths of Nature?

You are far nearer a knowledge of what is happening in the Universe, but as to why it happens or how it happens you have certainly had little opportunity to learn, and perhaps never will have. Even the difference that Thomson announced as existing between positive and negative electricity does not truly stand the test of the New Theory, and a difference is set up between Energy and Velocity that seems needless. To accept the New View we must imagine an Alpha particle coming from Radium. Some sort of an explosion has certainly happened, and say twenty electrons in some kind of a ball depart surrounded by a distant and surrounding sphere of positive matter. The electrons have velocity, and the sphere has mass. Upon expulsion into the Ether this atom is attracted toward an atom whose electrons are carrying a lighter load, or it wars on some worse-loaded atom. This is all there would be of "chemical affinity." Examples of the natural grouping of negative poles inside a positive field are secured in Mayer's experiments, where he has floated from one to twenty corks with needles on water. Each cork shows a tiny negative pole above water and under the



VIEW OF THE "ARCTIC CASCADE" IN THE LABORATORY OF THE UNIVERSITY OF LEYDEN—THE COLD OF OUTER SPACE.

THE UNIVERSITY of Leyden, near Amsterdam, Holland, on the Rhine, celebrated for so many things in the realm of knowledge, gave to the electrical world the Leyden Jar (see pages 44, 96), that is, the first accumulator. Now the same University has been the first in the world to equip for general and free scientific observation and use, a complete Laboratory of Refrigeration (cold-making), under the management of Professor Kamerlingh Ohnes, whose experiments have been well known in scientific circles for over a quarter of a century. The First International Cold Congress convened at Paris, October 12, 1908, and, within four years of that epoch, the establishment to be seen in the above photograph was in successful operation. Pursuing the methods of Professor Dewar (see page 225) and greatly elaborating on them through his own creative genius, Professor Kamerlingh Ohnes, has installed a battery of five coolers, which he calls a Cascade of five Cycles. He reckons temperature in degrees of Centigrade (see page 236), and a degree Centigrade is equal to 1.8 degrees Fahrenheit. His terms of Centigrade we will transform into terms of Fahrenheit, so as to be clearly understood. In the first cycle of retorts where Methylchloride (gas) is used, the temperature descends to 162° below zero Fahrenheit; in the second cycle, where Ethylene is the absorber, temperature is reduced further to 288° below zero Fahrenheit; in the third cycle, with Oxygen acting, the cold falls to 378° below zero Fahrenheit; in the fourth cycle, with Hydrogen the cold reaches 466.2° below zero Fahrenheit; and in the fifth and final cycle, completing the Cascade, where Helium becomes a solid, very nearly the theorized absolute zero of outer space among the stars is registered, at 491.4° below zero Fahrenheit. (See, particularly, paragraph at top of page 13, where Professor Ohnes sent word to Professor Dewar, in 1908.)

With the cold of outer space at hand—in a tiny world where all is solid except the ghostly elements, such as Nebulum, Aurorium, Coronium, Asterium, etc.—experiments of the utmost importance to human knowledge may be carried on. For one thing, Professor Ohnes has obtained the most powerful Magnetic Fields (see page 31) by introducing electric

currents of great intensity into very small coils that have been cooled to very low degrees. That is, Resistance resulting in heat and fire (see pages 21, 47, 49) would not come so quickly even in small bodies so very cold.

Not only are the secrets of metallic bodies to be further exposed through the ease with which these experiments may now be made, but other surprising facts have already come into view. The problems and nature of Life are now under careful observation in a manner never possible before. It is found that Life does not permanently cease to be when subjected to cold even as low as 455.4° below zero Fahrenheit. It is found that in these low temperatures, both seeds and the lower animals "may be often considered as machines at rest but ready to run"—clocks that have stopped, but may be started again in a higher temperature. (See chapter on Life, page **316**, and also the Life of Matter and Dastre's views, at page 224.)

Man now possesses opportunities to observe the constitution of so-called Matter and its phenomena under conditions all the way from 491 degrees below zero Fahrenheit to the superheat of Moissan's electric furnace (see page 241), some 2,500 degrees above zero. Through this vast range of conditions as to movement, the two kinds or aspects of Electricity must play their parts under the keen eyes of advancing Man.

The first decade of the Twentieth Century ushered astonishing discoveries and victories. The second decade is extending their utility in the most promising and gratifying ways.

To use a figure of speech, a front porch, a grand entrance, has been added to the imposing structure of the hypotheses of Avagadro and John Dalton (see pages 229-233), whereas, not long ago, it seemed inevitable that the whole building must be torn down.

If we believe the outer Universe to be a system of starry units, then each speck of Matter on earth, often 50,000 times invisible, is in itself a gathering and a machine of units not less numerous.

influence of the positive field above and beneath them, the corks form into defensive concentric rings. Prof. Duncan suggests 225,000 electrons inside the positive field of a Radium atom (atomic weight of Radium 225).

After all, what has Mendeléeff's brain made possible?

The physicists have pursued the atoms of matter by stages back to the Ether, and logically would reduce all to Electricity; but as they must have two kinds of Electricity we might as well content ourselves with Matter and Motion, and as at p. 316, nothing has as yet happened to abolish the other separate thing called Life. The unity of Matter is establishing itself in the minds of investigators, or its duality as positive and negative, thus abolishing Electricity. To abolish Matter, however, would require new senses in man, and a development of receptivity that probably has not been attained.

Give me some concluding illustration or manner of thinking concerning ions, electrons and Ether.

This hypothesis may, for instance, be considered: That the everlasting movement of electrons is the cause of X (and other) Rays in the Ether; that the electrons, in companies of great number, reaching into the hundreds of thousands, gather or seek a "load" of a character less mobile, and that the electrons thus loaded or surrounded in the Ether or by the Ether are ions or perhaps atoms; that, in the operation of loading, it is only in the Zero Group of Mendeléeff that the electrons get in a position of perfect balance (so far as chemists know) and thus fly around as atoms or ions or molecules that will have nothing to do with any other ion; that in the other groups the electrons are so feebly or inconveniently affixed to their burden that on coming near an ion with a different number of electrons or a different mass to carry, some electrons may escape and join the other ion; that these ions of the eight changeable groups may make temporary unions into the molecules of particular Elements, and these molecules may also make temporary unions into chemical compounds of varying degrees of stability. Also that electrons seem to be Velocity; that the load forming the ion

seems to be Mass; that the electrons seek always to conserve their Velocity or economize Work; that the fortuitous or chance lack of balance among electrons keeps the phenomenon of what we call Matter constantly before us; and that, in all probability, the atoms in the molecules of any Element may separate into unattached atoms, and the electrons in the unattached atoms may so escape or welcome visiting electrons as to render the unattached atoms capable of becoming a component part of another Element, and that this actually did happen when the Element Radium through its Emanations became the Element Helium. At last, in the blue stars, what we call Matter has gathered in ions or atoms only large enough to form Asterium, of which we know nothing (as in the cases of Nebulum, Coronium, Aurorium) save that it shows its own Fraunhofer lines in the most powerful spectroscopes. Again, Velocity and Mass have been experimentally and positively reduced to smaller units in order to adjust the ideas of Avogadro and Dalton to the now known and once unknown radio-activity of Matter. Thus we have Matter and Motion; and the X Rays and Emanations may yet unveil some of the mystery of Life. If man had not made this later adjustment, he would have been forced to abandon the much admired and very useful hypothesis of the "Conservation of Energy" (p. 17).

How does Science come Home to Me, myself?

Probably its most noticeable effect lies in the cheapness, the profusion or variety, and the excellence of your footwear, where Invention and Chemistry are both at play. A knowledge of the laws and theory of Chemistry has to do with every article of your raiment (see "Clothes"). The discovery and use of the Elements in the Cerium Group (pages 289 and particularly 548) have led to the astonishing success of the incandescent gas-lamps through the medium of the Welsbach mantle and its improvements. At your home your eye rejoices in the presence of products of the potter's art (see Chapters on "Glass" and "China") which could only have been owned by kings a century or so ago. Note, also, at page 549, and in fact throughout this present chapter on the "Advance of Science," why Uranium and

THE GENIUS OF INVENTION PRESENTING HER DISCOVERIES TO INDUSTRY.

the other radio-active Elements impart to your most beautiful pieces of glassware and chinaware their attributes of iridescence and opalescence. The laws and theory of Chemistry led a chemist, Faraday, to the principles of the dynamo and electromotor, and now, for a petty sum, you have at your command, in the electric car, the equal or the superior of the costliest automobile. On the way to the discovery of the principles of the dynamo, the methods of electrolysis (electroplating) were improved to the point that now makes metallic tableware at once so cheap, serviceable and beautiful. These matters are treated in our chapter on "Electricity" (pp. 87-90, 282). The portraits in your album and on your walls are triumphs of the study of the laws and theory of Light, as described in our chapters on "Photography" and "Light," and elsewhere (see Index). Should bodily misfortune come upon us in the nature of broken bones or gunshot wounds, the X-ray machine is at hand to guide the surgeon in his humane operations, and, besides the chapter on the X-rays, the pages which are just closing give a sufficient study of the nature and development of the electric vacuum tubes. Of that science of Chemistry, it may be truly said as a whole that its results so permeate our lives that, in a volume like THE FIRESIDE UNIVERSITY, intended primarily for useful purposes, nearly every chapter deals with Chemistry. Whether we turn to Electricity, Sugar, Clothes, China, Glass, Paper, Photography, yes, even Astronomy, there we shall always see what Chemistry has done to make our lives more satisfactory. In the preparation of nearly all our foods, the chemist still has his most mysterious problems, and, in fact, it is by this road that most of his discoveries have been made. His triumphs, too, in the variation of dyes, paints, pigments and varnishes are (outside of the apparent works of Nature herself) the chief delights of the human eye. Finally, one cannot become well acquainted with the contents of THE FIRESIDE UNIVERSITY without a profounder contemplation of the laws of Nature and the rapid progress of our race.

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ABBREVIATIONS.—Des., for "described;" ill. for "illustrated."